TREASURY DEPARTMENT
Public Health and Marine-Hospital Service of the United States

HYGIENIC LABORATORY—BULLETIN No. 77
JULY, 1911

# SEWAGE POLLUTION OF INTERSTATE AND INTERNATIONAL WATERS

## WITH SPECIAL REFERENCE TO THE SPREAD OF TYPHOID FEVER

## I. LAKE ERIE AND THE NIAGARA RIVER

By

ALLAN J. McLAUGHLIN

WASHINGTON
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## CHARTS.

MAPS.

# SEWAGE POLLUTION OF INTERSTATE AND INTERNATIONAL WATERS WITH SPECIAL REFERENCE TO THE SPREAD OF TYPHOID FEVER.[1]

## INTRODUCTION.

Sewage pollution of a water supply shows that the spread of Asiatic cholera, typhoid fever, and other diseases by that supply is possible and depends only upon the presence of certain pathogenic organisms in the sewage.

As it is very difficult, if not impossible, to prevent all typhoid or cholera stools from reaching the sewers, the only remedy is to secure a pure water supply by proper disposal of sewage and filtration or treatment of the water.

In discussing the question of pure water supplies it will be impossible to separate this prime requisite of sanitation from its twin—disposal of sewage.

It is equally impossible in America to separate these twin sanitary necessities from a direct relationship with the prevalence of typhoid fever.

### RELATION OF A SEWAGE-POLLUTED WATER SUPPLY.

The relation of a sewage-polluted water supply to the typhoid fever death rate is so well known that it seems unnecessary to dwell upon it. The coincident drop in typhoid fever rates with an improvement in the water supply has been observed in hundreds of instances. The following charts show graphically this reduction of typhoid fever death rates in some of our large cities. In view of the number of instances, this reduction must be regarded as something to be expected rather than as a coincidence. For the material from which the charts were compiled I am indebted to George C. Whipple's excellent work on typhoid fever and to the reports of the Census Bureau and the New York State Board of Health. The data for Milwaukee were furnished by Passed Assistant Surg. W. C. Rucker, Public Health and Marine Hospital Service.

In Milwaukee the typhoid curve indicates that the steadily increasing sewage pollution with the rapid growth of the city is again making itself felt, and some further steps are now necessary either to prevent this pollution or to purify the water supply.

The experience of Milwaukee is almost identical with that of Chicago and Cleveland, illustrating how temporary relief is gained by sub-

[1] Manuscript submitted for publication May 4, 1911.

stituting lake water for polluted wells. As the pollution of the lake increased, moving the intake farther out again produced temporary relief.

Chart 2 shows the change in typhoid death rate of Newark, N. J., coincident with the change from a polluted supply (Passaic River) to the Pequannock River.

The sharp drop after installation of the Pequannock supply and discontinuance of the use of Passaic River water is very noticeable. The resumption of the use of Passaic River water for a short period in 1899 is significant coupled with the rather sharp rise in the typhoid curve for that year.

Paterson, N. J., accomplished the reduction in its typhoid fever death rate and the purification of its water supply taken from the Passaic River at Little Falls by means of a mechanical filter installed in 1902.

Lowell, Mass., suffered severely from typhoid while using unfiltered Merrimac River water. In 1896 the Merrimac River was abandoned as a source of supply, and water from driven wells was substituted.

Lawrence, Mass., and Albany, N. Y., illustrate what may be accomplished by filtering a badly polluted river water.

Binghamton, N. Y., furnishes an excellent example of the relation of polluted river water used as a public water supply and the typhoid death rate, and also illustrates what may be accomplished with mechanical filtration and a coagulant in purifying water from certain badly polluted rivers.

## RELATION OF OTHER FACTORS TO THE TYPHOID FEVER DEATH RATE.

As shown above, the installation of a safe water supply usually reduces a high typhoid death rate. The rigid inspection and control of milk in all probability will still further reduce the incidence of typhoid fever. After these factors, water and milk, have been eliminated there will remain, however, a certain reduced typhoid rate, which is due to other causes. This persistence of typhoid fever in a city or town independent of the water and milk supply depends upon failure to dispose of in a proper manner or care for the excreta of persons infected with typhoid organisms. Carriers come into a community and often remain undiscovered. Many mild or ambulatory cases are never diagnosed as typhoid. Often because of poverty or other reasons no physician is called, and the case is unreported. This is especially frequent in the mild or atypical cases of children. Even if a physician is called, he may fail to diagnose typhoid because typical symptoms are absent or masked by other conditions. The physician's diagnosis and institution of preventive measures may be tardy, leaving a period during which the excreta are uncontrolled. Often, too, the case is discovered early, reported promptly, and proper

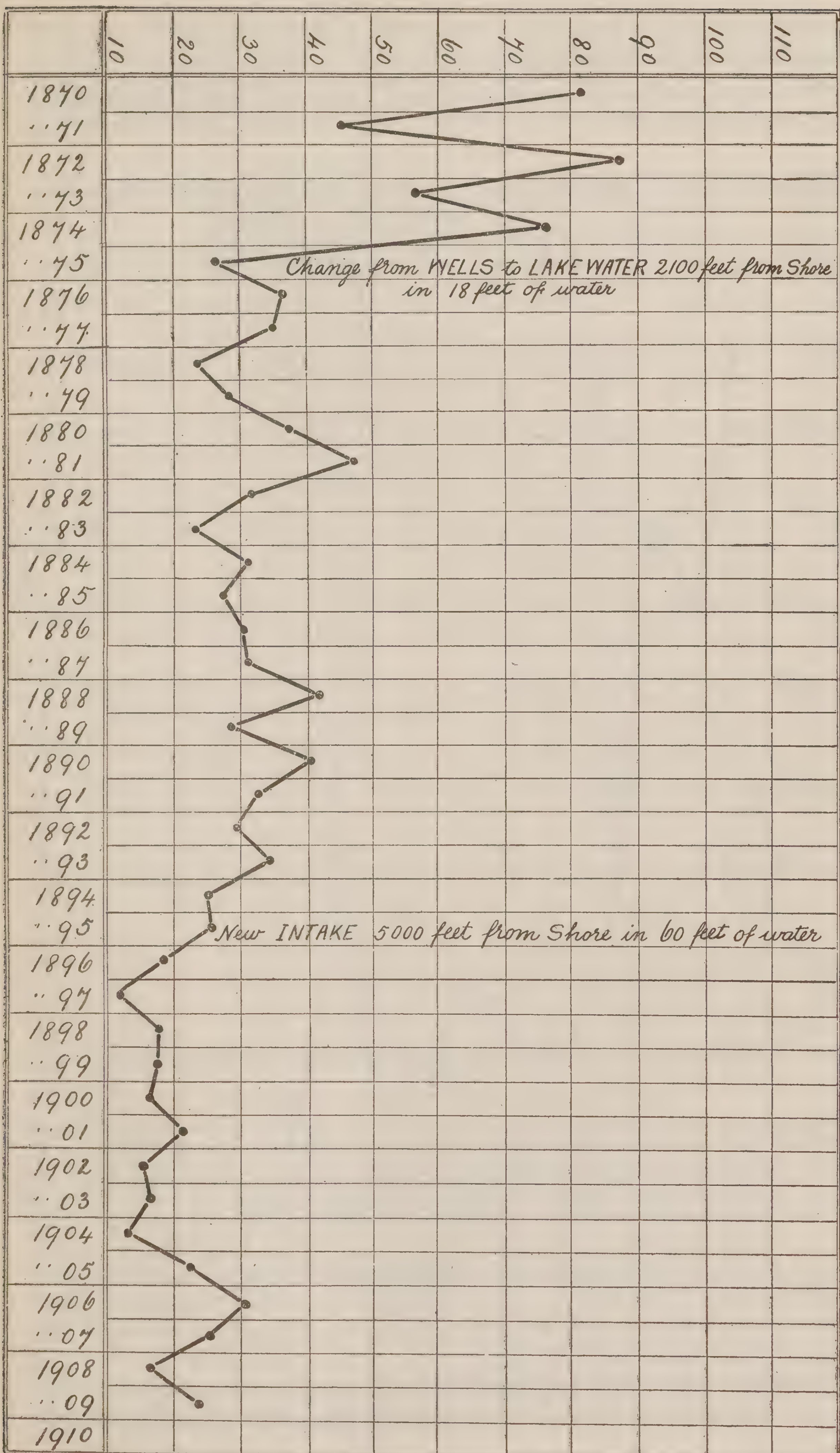
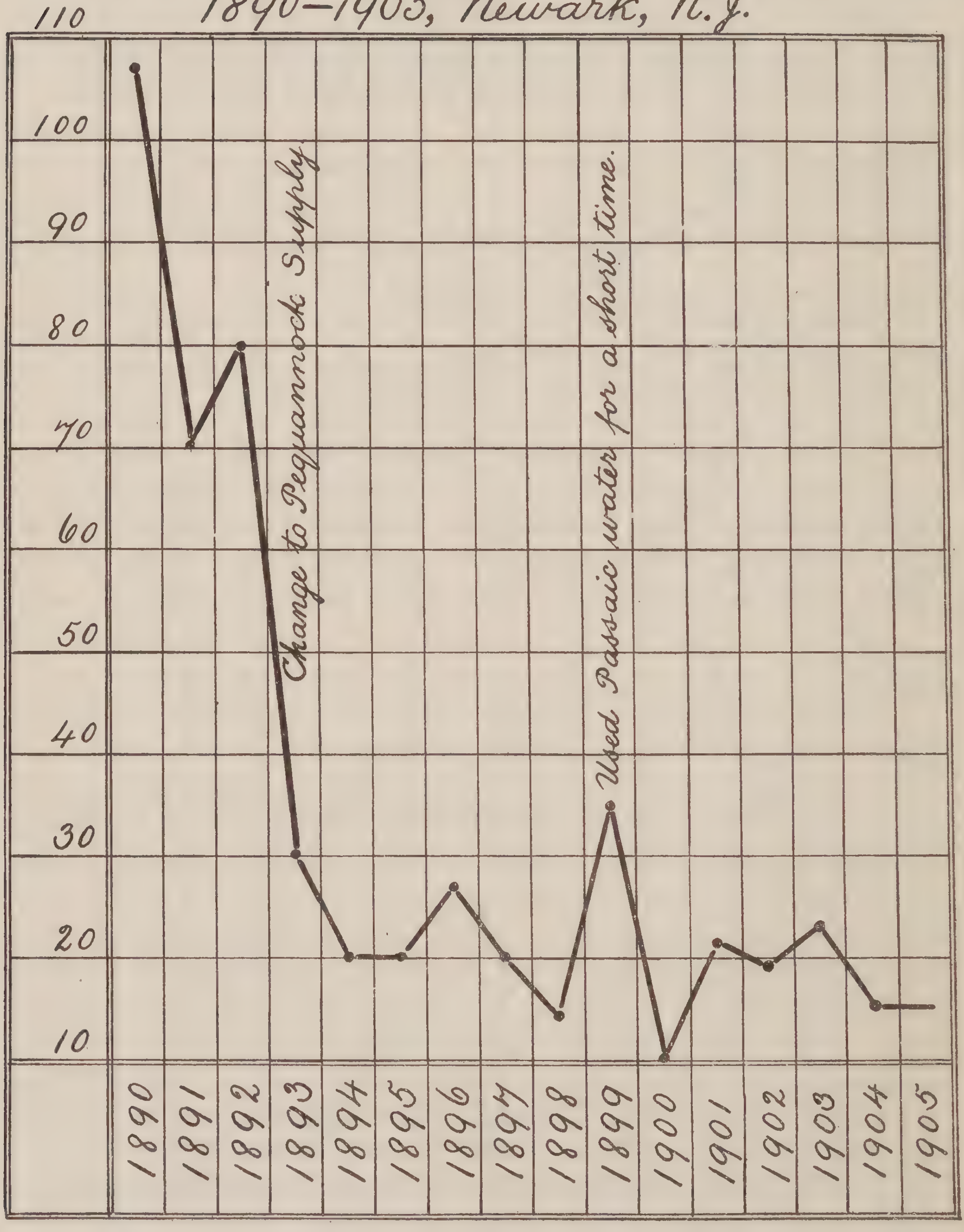



Chart I. Typhoid fever Deaths per 100,000, 1870–1910, Milwaukee, Wis.

instruction given in prophylactic measures, but for some reason these measures are not executed properly.

Persons are frequently discharged as cured or convalescent while still discharging typhoid bacilli in their excreta, without being

Chart II. Typhoid fever Deaths per 100.000, 1890–1905, Newark, N. J.

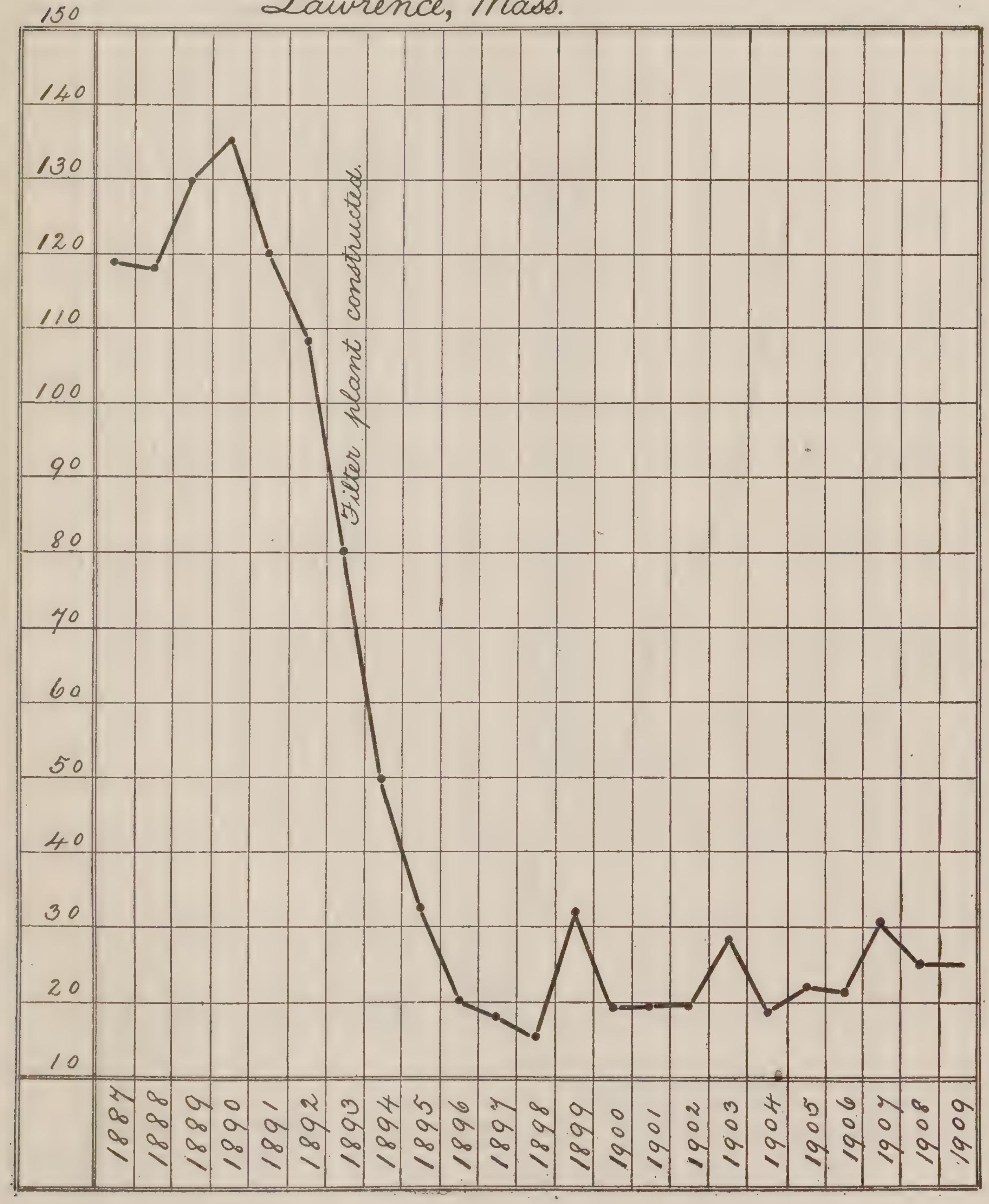



informed of the fact that they are likely to spread the disease unless certain precautions are observed.

In these various ways typhoid excreta are allowed to get beyond control and contact infection results. In this large class of cases not

traceable to the general water supply nor to milk the infection is more or less direct, and the period of time involved in the transfer of typhoid organisms from one human intestine to another is probably very short.

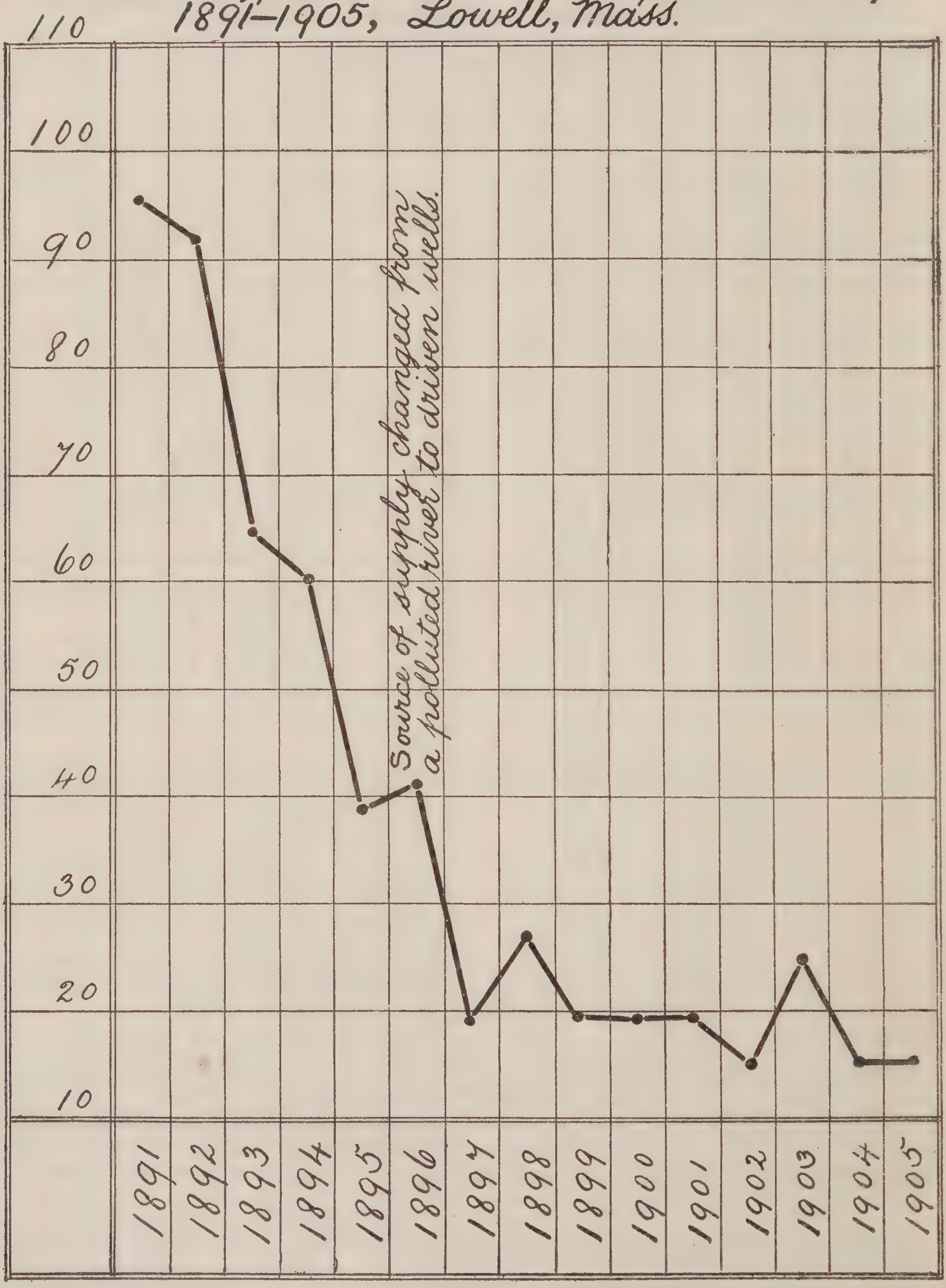
Chart III. Typhoid Fever Deaths per 100.000, 1887–1909, Lawrence, Mass.




The writer has no desire to magnify the importance of water as an agent in the transmission of typhoid fever. Neither is it his intention to underrate the importance of the factors responsible for endemic typhoid. Special stress is placed upon water-borne typhoid because of its wide prevalence in the United States and the comparative ease with which it may be eliminated.

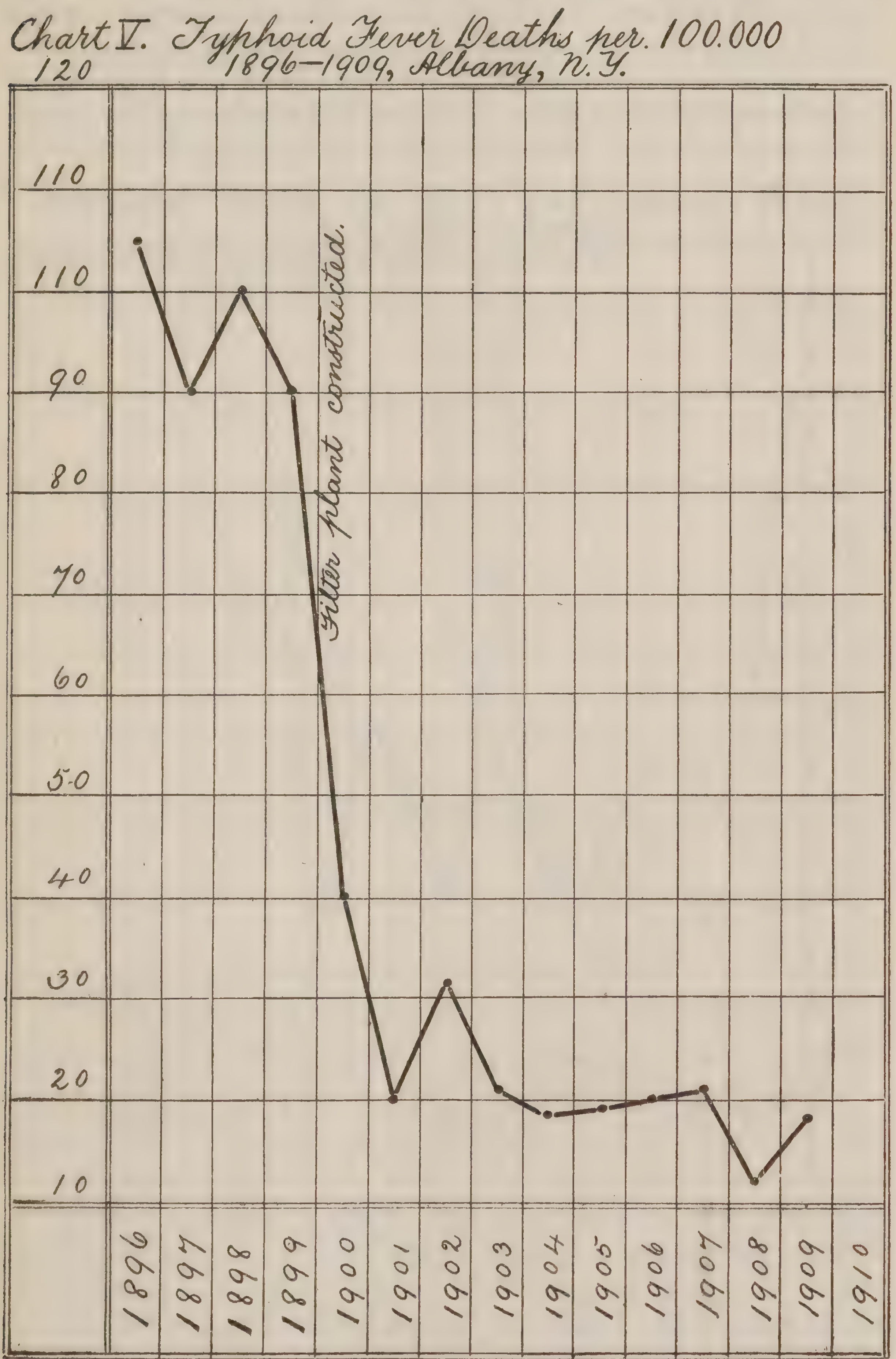
The eradication of the "residual" typhoid, or the typhoid which remains after the installation of a safe water supply, depends upon the cooperation of an intelligent public and honest, conscientious

Chart IV. Typhoid Fever Deaths per 100.000, 1891–1905, Lowell, Mass.




physicians with the health officers. Needless to say, this is an ideal condition seldom if ever realized. In contrast to the difficult problem presented by the endemic or residual typhoid, the prevention

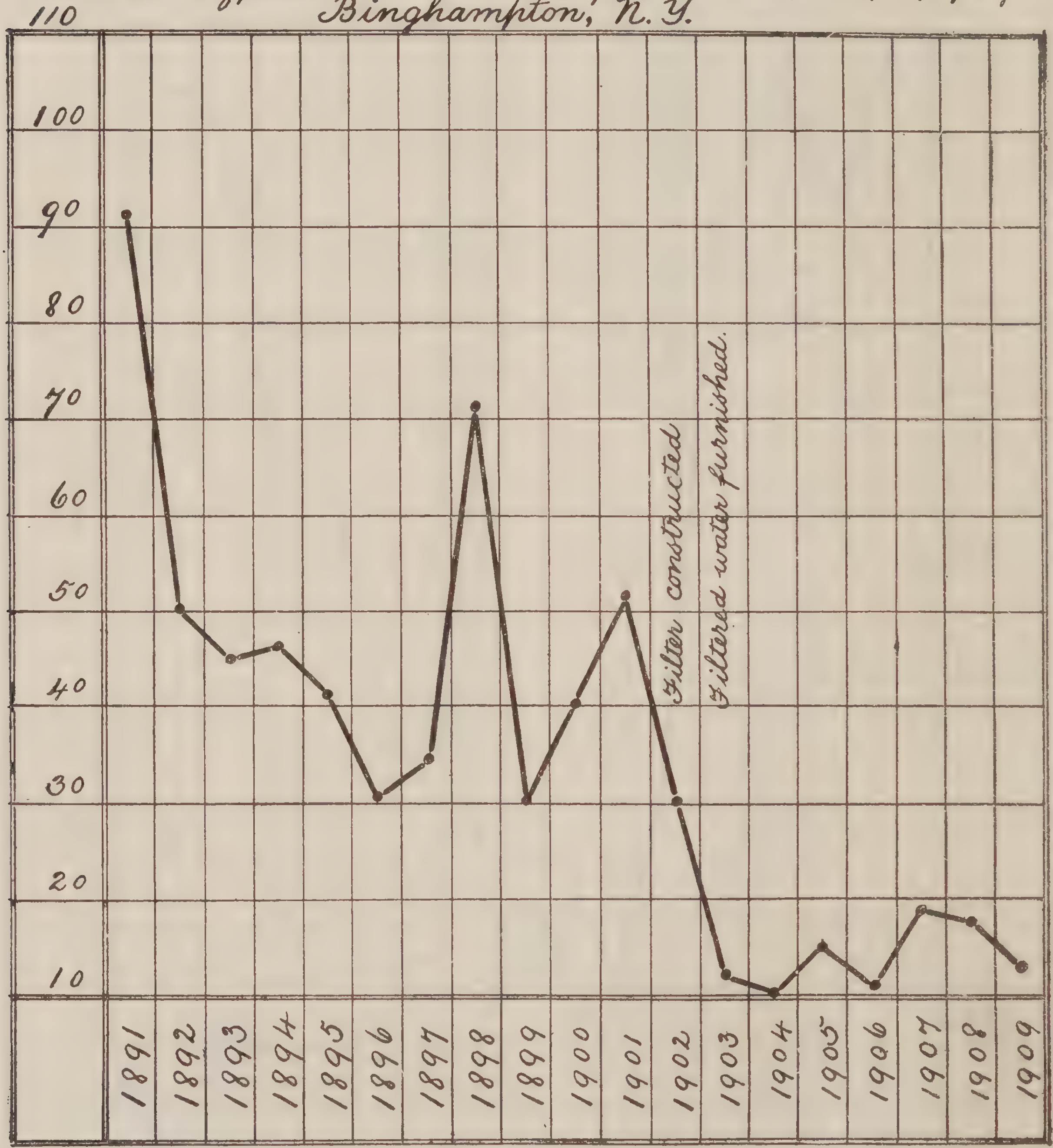
of water-borne typhoid seems relatively less difficult, and depends upon the furnishing of a safe water supply by municipal governments.




Thus it is clear that the combating of typhoid fever may be divided into two stages, first, getting rid of the typhoid due to a

polluted water supply, and, second, combating the so-called residual or contact typhoid. Many American cities have not even progressed as far as the first stage—that of providing a pure water supply. Many others have provided themselves with a pure water supply, and with smug complacency rest satisfied with the diminished rate if it is below 20 deaths per 100,000. Many physicians and even sanitarians speak of this rate of 20 as a "normal" typhoid rate, and refer to it as a

Chart VI. Typhoid Fever Deaths per 100.000, 1891–1909
Binghampton, N. Y.

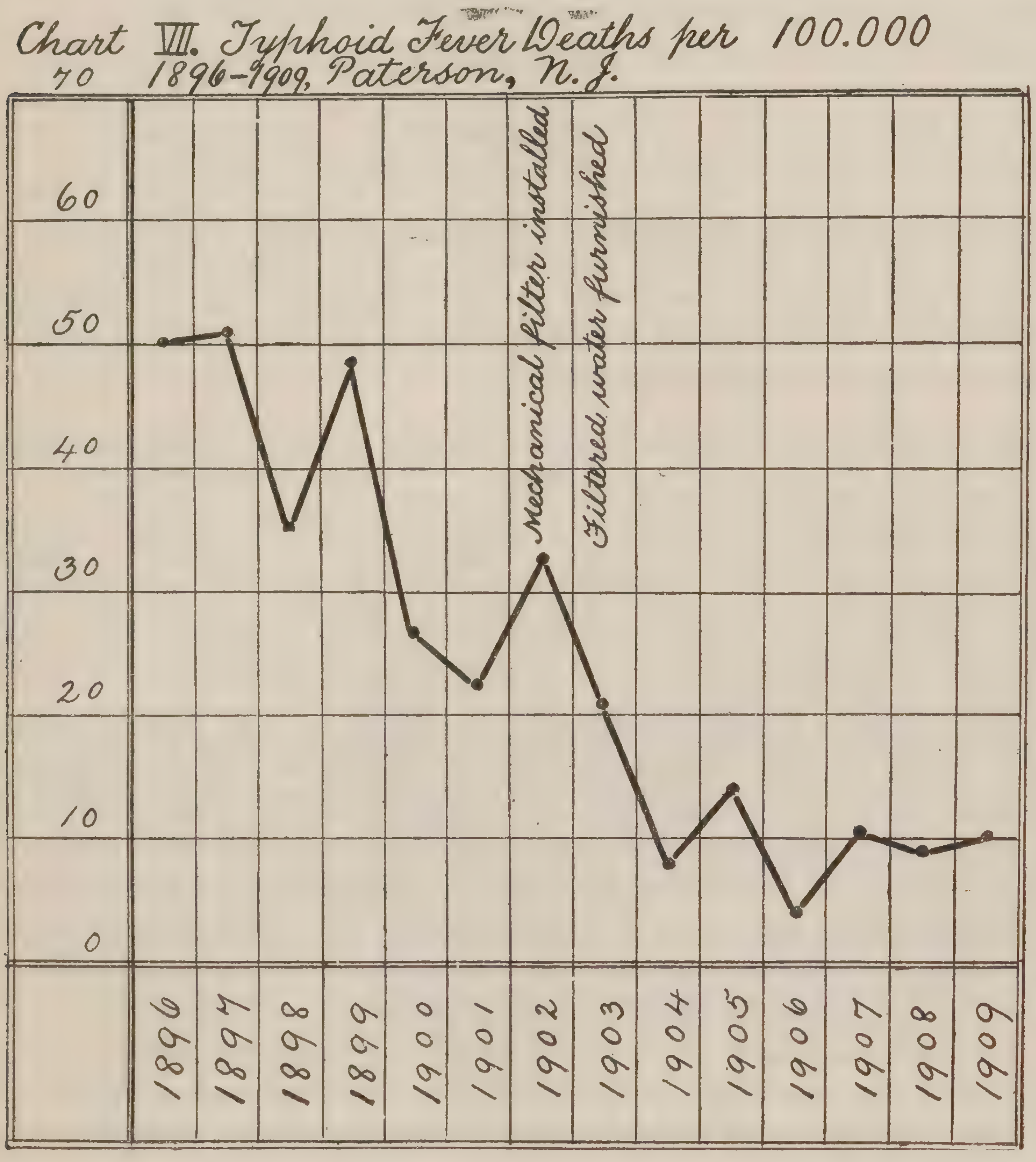



thing to be expected and accepted. While a reduction from 50 to 20 deaths per 100,000 is a creditable performance, a record of typhoid fever of 20 or even less per 100,000 is not a thing to be proud of; it is something to be attacked with all the vigor which governmental forces possess. How long would 20 deaths per 100,000 from Asiatic cholera be tolerated in an American city without strenuous efforts being directed toward its complete eradication? The analogy between the two diseases is perfect except that typhoid fever is the

more dangerous in transmissibility, because the urine in cholera is believed not to be infective, and cholera bacillus carriers do not carry the organisms for such long periods as is the case with typhoid.

### ANALOGY BETWEEN TYPHOID FEVER AND ASIATIC CHOLERA.

The striking similarity between the two diseases, Asiatic cholera and typhoid fever, especially in their modes of transmission, suggests another reason why American municipalities should accomplish




their manifest duty and provide a pure water supply with adequate protection against fecal contamination, as the possibility of the entrance of a cholera bacillus carrier must often seem imminent.

The number of typhoid deaths per 100,000 population,[1] which a city or town may reasonably be expected to have independent of the

[1] The typhoid death rate per 100,000 is deceptive and may be misleading applied to small cities of, for example, 10,000 population, where the importation of two cases ending fatally would raise the rate 20 per 100,000. This objection is inapplicable, however, even in small cities if the rate is persistently high for a period of many years.

general water supply is calculable, and varies in different cities, depending upon sociologic and perhaps climatic conditions. It is generally conceded that a persistent rate above 20 indicates a polluted water supply. This seems to be borne out by investigation of northern cities. However, a higher rate independent of water infection must be allowed for some southern cities, because of different conditions of life; for example, in Washington, D. C., after installation of a safe water supply in 1905, the rate remained above 30 until 1910.

*Deaths in Washington, by years, per 100,000 population.*

| | | | |
|---|---|---|---|
| 1904 | 47.0 | 1908 | 39.4 |
| 1905 | 48.2 | 1909 | 34.0 |
| 1906 | 52.3 | 1910 | 24.46 |
| 1907 | 35.5 | | |

## OBLIGATION OF MUNICIPALITIES TO PROVIDE SAFE WATER SUPPLY.

The typhoid fever death rate for 1909 for the whole registration area of the United States (18 States) was 22 deaths per 100,000 population, as shown by the following:

*Deaths per 100,000 population for the whole registration area of the United States, 1900–1909.*

| | | | |
|---|---|---|---|
| 1900 | 35.9 | 1905 | 28.1 |
| 1901 | 32.4 | 1906 | 32.1 |
| 1902 | 34.5 | 1907 | 30.3 |
| 1903 | 34.4 | 1908 | 25.3 |
| 1904 | 31.9 | 1909 | 22.0 |

This shows a steady progressive reduction in the typhoid death rate, which is very creditable, but the death rate of 22 is greatly exceeded in many communities, and the persistent effort of sanitarians to reduce this rate should be continued until typhoid fever ceases to be a menace to the traveling public. The citizen at home knows local conditions and may protect himself. The citizen traveling is at the mercy of hotels, steamboats, and railroads furnishing food and drink from sources unknown to the traveler.

There remains still much to be done in combating the spread of typhoid fever before the traveler will be as safe from this menace as he would be traveling in Germany or other European countries with low typhoid rates.

The low rate for the registration area of 22 deaths per 100,000 population is made possible by the splendid work which has been done in many of our larger cities, and there is a special obligation upon those cities which still have a rate in excess of the average to do more sanitary work in combating typhoid fever. This obligation is particularly binding if the city is situated upon the great highways of commerce or travel, or if the city, by reason of its business pros-

perity, the beauty of its surroundings, or for any other reason, attracts large numbers of visitors.

Our sanitary history for the past 50 years has been a record of apathy on the part of the American people toward the unrestrained pollution of our lakes and streams. There has been an attitude of indifference toward the character of public water supplies unless those supplies happened to have a disagreeable taste or odor. Instances may be cited where a public water supply grossly polluted with sewage and an appalling typhoid rate were accepted without murmur by the citizens for years until the taste of oil or of chemicals caused a popular demand for moving the intake farther out into the lake, or for a filtration plant.

In a growing town a public water supply more often is secured in place of wells because of the need of fire protection than to protect the public health. Installation of a sewer system is usually done to prevent nuisance rather than to safeguard the public or private water supplies.

Installations of sewage-disposal plants are more often made to obviate a nuisance than to protect a water supply from gross pollution.

The furnishing of safe drinking water is a sanitary necessity of primary importance and a public duty which municipal officials can not evade. Municipal officials need not expect that typhoid will disappear upon the installation of a safe water supply. The existence of other factors in the spread of typhoid fever does not, however, absolve them from the obligation of providing a safe water supply for the public. Sooner or later a sewage-polluted water supply will produce an explosion of typhoid fever and stamp the officials in charge as guilty of culpable negligence. Aside from the loss of life and pecuniary loss to the individual, the municipality probably in the future will be exposed to serious financial loss because of damage suits such as have been brought recently in Mankato, Minn.[1]

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[1] "Liability of municipalities for deaths from typhoid due to negligence in permitting water furnished to become contaminated." Journal American Medical Association, Vol. LVI, Jan. 7, 1911, p. 65.

## TYPHOID FEVER IN THE UNITED STATES.

The prevalence of typhoid fever in the United States as compared with foreign countries is shown in the following table:

[From the United States census reports.]

| Country. | Deaths from typhoid fever per 100,000 of population. | | | | |
|---|---|---|---|---|---|
| | Annual average, 1901–1905. | 1904 | 1905 | 1906 | 1907 |
| Austria | 19.5 | 19.3 | 17.8 | ........ | ........ |
| Belgium | 16.8 | 14.9 | 13.7 | 12.3 | ........ |
| German Empire | 7.6 | 7.0 | 6.3 | ........ | ........ |
| Norway | 5.3 | 4.4 | 3.8 | 5.5 | ........ |
| Sweden | 8.6 | 5.1 | 9.8 | ........ | ........ |
| Switzerland | 6.2 | 7.7 | 5.0 | 4.8 | ........ |
| England and Wales | 11.2 | 9.3 | 8.9 | 9.2 | 6.7 |
| Scotland | 11.4 | 8.9 | 8.0 | 8.5 | ........ |
| Ireland | 13.1 | 10.6 | 11.4 | 9.0 | 8.3 |
| United States registration area | 32.2 | 31.9 | 28.1 | 32.1 | 30.3 |

It must be remembered that the above figures for the United States represent only the registration area comprising 17 States—74 registration cities and the District of Columbia. It is safe to assume that conditions outside of the registration area are worse than in the progressive States and communities which are far enough advanced in sanitation to have a system of collection of vital statistics and sufficiently public spirited and humanitarian to transmit their statistics to Washington for the benefit of the general public.

If we compare American cities with European cities, the showing is even worse than a comparison made between countries.

The following table shows 10 large European cities in 10 different countries and 12 American cities having more than 100,000 population for the same period (1906, 1907, 1908):

| City. | Deaths from typhoid fever per 100,000 of population. | | |
|---|---|---|---|
| | 1906 | 1907 | 1908 |
| London | 6.0 | 4.0 | 5.0 |
| Edinburgh | 3.0 | 3.0 | 2.0 |
| Paris | 11.0 | 10.0 | 8.0 |
| Rotterdam | 11.0 | 10.0 | 5.0 |
| Copenhagen | 4.0 | 2.0 | 7.0 |
| Stockholm | 2.0 | 2.0 | 1.0 |
| Christiana | 4.0 | 2.0 | 2.0 |
| Berlin | 4.0 | 4.0 | 4.0 |
| Vienna | 5.0 | 3.0 | 4.0 |
| New York | 15.4 | 17.5 | 12.3 |
| Chicago | 18.3 | 17.7 | 15.3 |
| St. Louis | 18.3 | 16.3 | 15.3 |
| Cleveland | 20.2 | 18.9 | 12.6 |
| St. Paul | 21.1 | 17.1 | 12.0 |
| Providence, R. I. | 19.2 | 8.2 | 16.9 |
| Fall River | 7.6 | 17.9 | 13.2 |
| Worcester | 11.5 | 14.4 | 10.5 |
| Rochester | 17.2 | 16.4 | 11.9 |
| Syracuse | 10.1 | 15.8 | 15.4 |
| Paterson | 4.4 | 11.4 | 9.5 |
| St. Joseph, Mo. | 11.9 | 14.1 | 13.0 |

These 12 American cities are selected because they have the lowest typhoid rates in their class among American cities.

Only one European city is given in each country, but in the countries named many other large cities are found with equally low typhoid rates. For example, in Germany, in addition to Berlin, we find that Hamburg, Dresden, Breslau, and Munich all have average rates for the three years of 5 or lower.

| City. | Typhoid death rate per 100,000 population. | | |
|---|---|---|---|
| | 1906 | 1907 | 1908 |
| Berlin | 4 | 4 | 4 |
| Hamburg | 4 | 3 | 4 |
| Breslau | 5 | 4 | 5 |
| Dresden | 7 | 2 | 6 |
| Munich | 2 | 3 | 3 |

The low typhoid death rates of large cities in Germany, England, Scotland, Denmark, Norway, and Sweden is due in the greatest measure to good, safe water supplies. In combating typhoid fever the typhoid infection divides itself into two distinct portions, (1) that which is waterborne; (2) that which remains after installation of a safe water supply.

The first portion is the most important because of its enormous potentialities for disaster on a large scale. Therefore the prime necessity in the prevention of extensive outbreaks of typhoid fever is a safe water supply. After the installation of a safe water supply the typhoid death rate will be reduced to a rate corresponding to the general sanitary conditions existing in the municipality, and the most difficult portion of the fight against typhoid begins at this point.

As indicated above, many of our American cities have not yet progressed so far as the prime necessity itself—a safe water supply.

Others have installed safe water supplies and plume themselves on their achievement. They are so pleased with the very great success of reducing a typhoid rate from 80 or 100 to 18 or 20 that they are prone to rest on their laurels and compare their rate with that of less-fortunate cities.

Some cities have water supplies "more or less" safe, which receive pollution at times or in very great dilution. These cities have too many cases in the winter and spring months to be normal, but not enough to cause public alarm. By good strenuous work along other lines of prevention, such as control of milk, early discovery of cases, etc., the rate for the year, in spite of these winter cases, is kept below 30 or possibly below 20. Such municipalities delude themselves into the belief that their typhoid is not waterborne and that their water supply is not at fault.

Unfortunately there is still another type of American city whose citizens patiently accept sewage-polluted water as something unavoidable. The officials in these latter cities often do not know of or appreciate the relation between a polluted water supply and typhoid fever, and they consider the expense of providing a safe water supply or a proper disposal of sewage as unjustified unless their sense of taste or smell is offended.

In considering cities of more than 100,000 population it is easy to divide them into classes with regard to their water supply and general sanitary condition.

They group themselves naturally into these classes, and the same classification will serve in a general way for smaller cities and towns.

First, they may be divided into classes according to the water supply:

(1) Water supply safe.

(2) Water supply intermittently polluted with great dilution of polluting material.

(3) Water supply subject to intermittent and occasionally gross pollution.

(4) Water supply subject to gross constant pollution.

Second, these cities may be subdivided according to the other sanitary economic and social factors which bear upon the suppression of typhoid fever. These factors include the ability and willingness of the local medical men to diagnose and report promptly to the health office all cases of typhoid fever.

| Class. | Water supply. | Other sanitary economic and social factors bearing upon the prophylaxis of typhoid. | Probable typhoid fever rate per 100,000 of population. |
|---|---|---|---|
| 1 | Safe | (*a*) Excellent | 5 or less. |
| | | (*b*) Good | 5 to 10. |
| | | (*c*) Fair | Average of 15. |
| | | (*d*) Bad | 20 or higher. |
| 2 | Intermittent pollution with great dilution of polluting material. | (*a*) Excellent | 15 to 25. |
| | | (*b*) Good | |
| | | (*c*) Fair | |
| | | (*d*) Bad | |
| 3 | Intermittent and occasionally gross pollution. | (*a*) Excellent | Irregular. 15 to 60+. |
| | | (*b*) Good | |
| | | (*c*) Fair | |
| | | (*d*) Bad | |
| 4 | Gross, constant pollution | (*a*) Excellent | Consistently high, above 50 or even 100 for a period of several years. |
| | | (*b*) Good | |
| | | (*c*) Fair | |
| | | (*d*) Bad | |

Under this classification we have four classes of cities, each one of which has four subdivisions (*a*), (*b*), (*c*), and (*d*). Every one of our big progressive American cities should be in the first class, subdivision (*a*). As shown above, from 1901 to 1908 none of our large cities came in this class.

One factor which prevents our best cities from attaining greater success in the reduction of typhoid fever is the number of typhoid cases which come in from other communities. Real substantial success can only be achieved by simultaneous effort made over a wide area by all officials of the Federal, State, and municipal governments acting in hearty cooperation. The coordination of all these forces is a most difficult problem, and while all recognize its necessity few care to risk a suggestion as to how it can be secured.

*Cities with safe water supplies.*—In subdivision (*a*) of class 1, signifying that the sanitary social and economic conditions bearing upon the prophylaxis of typhoid are excellent, we should not have a typhoid rate above 5 per 100,000.

Cincinnati, Ohio, is the only large American city which has approached this standard, and this excellence was attained in 1910. It remains to be proved whether this very low rate for 1910 was a coincidence or whether it represents a permanent improvement which

would place Cincinnati in the same category as Berlin, Hamburg, London, and Edinburgh.

Several American cities have practically entered subdivision (*b*) of class 1. This signifies good conditions bearing upon the prophylaxis of typhoid plus a safe water supply. The typhoid rate in this subdivision should not exceed 10 per 100,000.

Jersey City, N. J., Rochester, N. Y., and Paterson, N. J., have had rates below 10, but a continued rate below 10 for several years is very rare in American cities.

Subdivision (*c*) of class 1, indicating fair conditions and a safe water supply with a typhoid rate below 15 per 100,000, takes in the American cities of St. Joseph, Mo., Providence, R. I., Scranton, Pa., Syracuse, N. Y., Fall River and Worcester, Mass., and others.

Subdivision (*d*) of class 1 takes in those cities with safe water supplies and bad conditions bearing upon the prophylaxis of typhoid and which in all probability have typhoid-fever rates above 15 per 100,000, and in some cases in excess of 30—Washington, D. C., Albany, N. Y., Philadelphia, Pa., and Toledo, Ohio.

*Cities with water supplies subject to intermittent pollution with great dilution of polluting material.*—This class includes those lake cities whose intakes are placed remote from sources of pollution in deep water whose great dilution of any occasional polluting material is effected. Dilution is influenced by the volume of water available for dilution, the time which must elapse in transit to the intake, and the amount of the polluting material.

Cleveland is a type of this class. The Celeveland intake is 4 miles from the mouth of the Cuyahoga, in 55 feet of water. Sewage pollution from Cleveland has to travel miles to reach the intake, and the opportunity for dilution is great.

Chicago, Milwaukee, Detroit, and Buffalo (new intake in the Emerald Channel) all belong in this category.

These water supplies are not safe. The pollution, though intermittent and diluted, may be responsible for many cases in the winter and spring months. In these big progressive cities the other conditions bearing upon typhoid prophylaxis are apt to be good, and a rather low typhoid rate is usually the result. But analysis of cases by months will often show a preponderance of cases in winter and spring.

*Cities with water supplies subject to intermittent and occasional gross pollution.*—A few large cities and a great many smaller ones belong in this category.

The type city of this class possesses an intake which is safe from pollution in good weather or under ordinary conditions for the bulk of the time, but which under certain storm conditions may be grossly polluted, and disaster in the shape of an explosive outbreak may follow.

Erie, Pa., since 1908 is a good illustration of this class. Milwaukee may also belong in this class rather than in class 2. In fact, the line between these two classes can not be sharply drawn. The typhoid curves for cities in class 3 are apt to be irregular and show great variations from year to year. When the typhoid rate makes a pronounced rise in these cities, it is found to be due to increase in the winter and spring months.

*Cities whose source of water supply is grossly polluted constantly.*—Fortunately, very few large American cities are now found in this class, although until 1908 Pittsburg, Allegheny, Cincinnati, Columbus, and Philadelphia belonged in class 4. Many smaller cities were notorious members, as Niagara Falls, N. Y., Cohoes, N. Y., and Escanaba, Mich. Plans have been approved for filtration plants at Escanaba and Niagara Falls, and a mechanical filter is being installed in Cohoes.

## UNDUE PREVALENCE OF TYPHOID FEVER A MENACE TO OTHER CITIES.

From the standpoint of the prevention of the spread of contagious disease from one State to another and in interstate commerce the undue prevalence of typhoid fever in large cities assumes a serious aspect.

Prof. William T. Sedgwick, [1] the foremost authority in the United States on the question of sewage pollution of streams, expresses his opinion of conditions at Niagara Falls as follows:

> For the citizens of Niagara Falls this condition is bad enough, but if the consequences were limited to the people of Niagara Falls the rest of the country might look on with comparative composure. In point of fact, the sewage pollution of the water supply of Niagara Falls is a matter not merely of local, but of national, concern, for Niagara Falls is visited annually by hundreds of thousands of people from all over the country, many of whom, after drinking the sewage-polluted public water supply, carry away with them the seeds of typhoid fever with which they afterwards sicken, and some of them have died in remote parts of the country, or even beyond the country. Furthermore, because every case of typhoid fever wherever it occurs is liable to become a focus of fresh infection, it is impossible to set any limit to the amount of sickness and death produced all over our country and even beyond its borders by the pollution of the water supply of Niagara Falls by the sewage of the city of Buffalo. For these reasons I consider the state of affairs which has long existed at Niagara Falls disgraceful both to the State of New York and to the United States of America.

Excessively high typhoid fever rates in cities of great industrial and commercial importance, whether they be situated on lake, river, or inland, indicate a great menace to the health of other communities. These cities are particularly culpable if they have an unsafe or polluted water supply, because of the thousands of travelers from other States exposed to infection from bad water, who are compelled to visit these cities for business reasons.

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[1] Sedgwick, Wm. T., Sc. D., "Shall we continue or shall we stop the sewage pollution of our streams?" Annual Report, New York State Department of Health, 1909, p. 460.

Cities which attract large numbers of tourists assume a similar importance in the spread of disease in interstate traffic, and a polluted water supply in such cities should not be tolerated.

No inconsiderable portion of this widespread typhoid infection is due to the pollution of interstate or international water supplies by municipalities situated thereon.

In fact, many of the largest cities are situated upon interstate or international waterways and contribute gross pollution to these bodies of water, at the same time taking their water supplies therefrom. Other large cities, if not situated upon interstate waters, are intimately connected by railroad or vessel with many other States.

The present work was inaugurated with the idea of ascertaining the exact conditions existing in cities and towns situated upon interstate or international waterways, with special reference to the spread of typhoid fever due to polluted water supplies. It is fully realized that after the installation of safe water supplies in these cities strenuous effort will still be required for the eradication of typhoid fever, but it is evident that our first duty is to rid ourselves of the odium of waterborne typhoid, which has been called, and with some reason, a national disgrace.

Valid excuses for polluted water supplies are ignorance and poverty, and no American community will care to advance either to explain such a state of affairs.

## LAKE ERIE AS A SOURCE OF WATER SUPPLY.

The importance of Lake Erie as a source of public water supplies can not be overestimated. At present there is an urban population on the United States shore of a million and a half of people. The density of population is bound to increase, and scarcity of other adequate supplies makes the adjacent population dependent upon the lake for water supplies for all time to come. Lake Erie contains 17,500,000 million cubic feet of water, which affords storage for the water discharged into it for about 920 days.

This great natural reservoir, with capacity for 920 days' storage, assures a high degree of purification by natural agencies, such as dilution, aeration, and sedimentation, besides affording the storage time necessary to permit of the natural death of pathogenic bacteria. The ability of the natural agencies operating in the lake to render sewage inocuous is very great, so that water at the center of the lake is comparatively pure.

Where the sewage in great quantity is poured into the lake, especially near the mouths of rivers upon which large cities are situated, the zone of polluted water is wide and a greater distance toward the lake center must be traversed before pure water is secured. With the growth of urban populations on the lake shore, this zone of

polluted water is continually widening, and waterworks intakes have been repeatedly moved farther out to secure better water. In the danger of polluted water entering waterworks intakes there is another factor besides the ever widening zone of polluted water, viz, the action of currents.

### CURRENTS OF LAKE ERIE.

Direction and velocity of the currents of Lake Erie may be said to depend entirely upon the wind.

The frictional action of wind upon bodies of water operates in three ways:

(1) Surface current in the direction of or "with" the wind.

(2) Piling up of the water on the shore directly opposed to the direction of the current and lowering of the water at the opposite end.

(3) Alteration of temperature by mixture and by importation of waters of different temperatures.

The first and second effects of wind action are the most important from a sanitary standpoint. The first because of its direct carriage of polluted water for considerable distances. The second operates in two ways—(1) the rapid lowering of water level carries the polluted water in the low end of the lake out of harbors into the lake; (2) after the piling up of water at the high end of the lake and without a change of wind, pollution is carried out of harbors by a "backwash" or undertow in spite of the persistence of a surface current toward the shore. The third effect, alterations of temperature, probably has little sanitary significance.

When an unusual disturbance of a large body of water occurs due to strong winds, the immediate results are as indicated above—a surface current in the direction of the wind, a piling up of the water on the lee shore, and a fall of the water on the weather shore. The return to stable equilibrium is effected by a series of rhythmic oscillations about a central nodal line. These rockings or oscillations are of decreasing amplitude until stable equilibrium is established, and in a comparatively long and narrow lake, with the wind in the direction of the long axis of the lake, resemble the motion of a child's seesaw or teeter.

### SEICHES.

This phenomenon was discovered on Lake Geneva and called by the Swiss "seiche," a name by which it is commonly known. The seiches on Lake Erie were studied and described by Henry,[1] who, in regard to fluctuations in lake level and seiches, says:

> The water that is transported by the winds from one end of the lake to the other can not return as a surface current, since the force which urges it forward naturally operates to prevent its return. The surface water that is drifted eastward across the

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[1] Henry, Alfred J., Wind Velocity and Fluctuations of Water Level on Lake Erie. Bulletin No. 262 U. S. Weather Bureau, Washington, 1902, p. 22.

Atlantic between latitudes 30° and 50° north and banked up against the Continent of Europe, unlike the lake waters, escapes in three ways, viz, downward, and to the northward and southward. In the case of Lakes Superior, Erie, and Ontario, which are so situated with regard to the prevailing winds that easterly surface currents must prevail, there is probably a small volume of water in excess of the normal flow brought to the eastern ends of the lakes by the winds.

This water, which ordinarily can not be of great volume, is usually disposed of through the natural outlets. When, however, strong westerly gales prevail, the volume of water piled up at the eastern end of the lakes is generally so great that it can not be carried off by the river outlets, nor can it return as a surface current; it must, therefore, escape downward and westward as a return current beneath the surface.

It seems probable that the first effect of a strong wind upon the waters of the lake is to transfer from one end toward the other sufficient water to disturb the condition of hydrostatic equilibrium which existed before the wind began. Shortly after the maximum force of the wind has been exerted the lake tends to return to a state of stable equilibrium. The water that has been piled up on the leeward shore of the lake will immediately recede, although the velocity of the wind may continue high for several hours after the water falls. A condition of stable equilibrium is reached by a series of rockings of the water of the whole lake about a nodal line passing through the center of the lake, the water at either end rising and falling alternately until a condition of rest is attained.

## STORM OF NOVEMBER 21, 1900.

The storm of November 21, 1900, a record of which appears in Table II, was the most severe of any experienced during the year. The wind at Buffalo attained a maximum velocity of 80 miles per hour (35.7 meters per second) from the west at 1.37 p. m., and continued to blow at an average of over 60 miles per hour (26.8 meters per second) until nearly 8 p. m.

The level of the lake rose sharply and the water in the canal backed up so that it reached the streets in the south portion of the city. The scale of the diagram upon which the water-level curves have been reproduced is not large enough to show the whole rise. The rise began at 8 a. m., when the wind had attained an average velocity of 36 miles per hour (16.1 meters per second), and continued until 4 p. m. At that time the lake level had risen 8.4 feet (2.5 meters) above the stage at 8 a. m. This extreme height was not long maintained; the water began to fall shortly after 4 p. m. and continued falling as rapidly as it had previously risen, so that by midnight the stage was 2 inches (50 millimeters) lower than at 8 a. m. The oscillation was completed in 16 hours. The reflex wave that began immediately after the primary wave had subsided reached a moderate height only, viz, 2 feet (0.61 meter) above zero.

The level of the lake at Amherstburg did not begin to fall sharply until 10 a. m., when the stage of water was 22 inches (0.56 meter) above zero. The fall continued until 4 p. m., reaching a stage of 33 inches (0.82 meter) below zero, a range of 4 feet 7 inches (1.38 meters). The rise at Amherstburg began at 5 p. m., nearly an hour after the fall had begun at Buffalo, and the water rose as sharply as it had fallen, passing beyond the initial stage and reaching a height of 34 inches (0.86 meter) above zero. This oscillation was completed at Amherstburg in 16 hours. The extreme difference in level between the two ends of the lake at any one time was 13 feet and 1 inch (3.98 meters).

It should be noted that the crest of the rise at Buffalo was reached just as soon as the wind began to slightly abate. The average velocity from 3 to 4 p. m. was 66 miles per hour (29.5 meters per second). During the next hour it fell to 62 miles per hour (27.7 meters per second) and the level of the water sank 2 feet 8 inches (0.81 meter).

In the succeeding two hours, although the wind was blowing with a velocity of 61 miles per hour (27.3 meters per second), the level of the water continued to fall at the rate of over a foot an hour.

### SIMILARITY OF LAKE ERIE TOWNS.

There is a striking similarity in Lake Erie towns in their general topography and the location of their waterworks intakes. They are usually built upon the shore of the lake at the mouth of a river. Sometimes they were originally a few miles from the mouth of the river, and as the ore traffic or other industries developed a harbor portion developed with them. There was a common impulse in all these towns to place their waterworks intake a little to the west of the mouth of the river, depending upon the prevalence of westerly winds to carry pollution away from the intakes. In the report of the Ohio State Board of Health for 1901, page 418, the following comment is made in regard to the prevalence of westerly winds:

> In the averages for the year the wind is from the west for a few hours only in excess of wind from the east. On an average there is almost as much likelihood of the wind blowing from the east as from the west, and for about four months in the summer and fall there is nearly always more hours of westerly winds than easterly winds. From the figures as given it must be conceded that an intake can not be kept free from sewage by any supposed constancy of the wind. While it is shown that the winds are from the west for a few hours more each year than they are from the east, yet there are enough hours of winds from the east to cause the surface currents to set decidedly toward the west.
>
> No data except that given are available as to the total wind movement in the different directions, but the remarkable uniformity in the velocity at Cleveland would prevent any great variation in the total movement from the total time.

### WINDS ON LAKE ERIE INCONSTANT.

The report of the deep waterway commission shows from the records of the Toledo weather station, that from 1891 to 1895 winds from the southwest, west, and northwest prevailed 56½ per cent of the time, and winds from the southeast, east, and northeast 27 per cent of the time. These reports show that west winds prevail for a period twice as great as east winds, but it also shows that for 16 months out of the 5 years the wind blew from the east.

The reports of the Cleveland stations of the United States Weather Bureau show that in June, August, September, and October the prevailing winds blow from the northeast, east, or southeast. In January the greatest number of hours of west winds obtains, and yet in this month the average excess of west winds over east winds is only a little over 150 hours per month; so that there may be winds from either direction at any time of the year, and the unreliability of winds as a matter of protection is manifest. The supposition that westerly winds protect the intakes entails the assumption that sewage pollution is carried at or near the surface of the water. The surface cur-

rent near the shore is in the direction of the wind and the general trend of the lake water in quiet weather is toward the east, but only at a rate of one-eighth to one-sixth mile per day.

In time of storm, with strong gales blowing for days in one direction, there is not only a surface current in that direction, but also a deeper current in an opposite direction. The amount of pollution that this deeper current carries depends upon local conditions, but to assume that all sewage pollution is carried at or near the surface is unsafe. It is certain that this deeper undercurrent carries gross pollution out of harbors and river mouths in times of flood even when the wind is blowing directly inshore, making a surface current toward the harbor and raising the level of the harbor water several feet.

## POSITION OF WATERWORKS INTAKES AS A MEASURE OF PROTECTION.

The curious dependence upon the fallacious belief that protection was afforded to lake intakes by the position of the intake to the westward of the source of pollution is paralleled by the faith which citizens of towns on the Niagara River had in the position of their intakes to the westward of a known polluted current. Even when it became generally known that, at best, position of the intake could afford but a slight and insecure measure of protection, seldom was the prompt and obvious remedy, filtration of the water, applied.

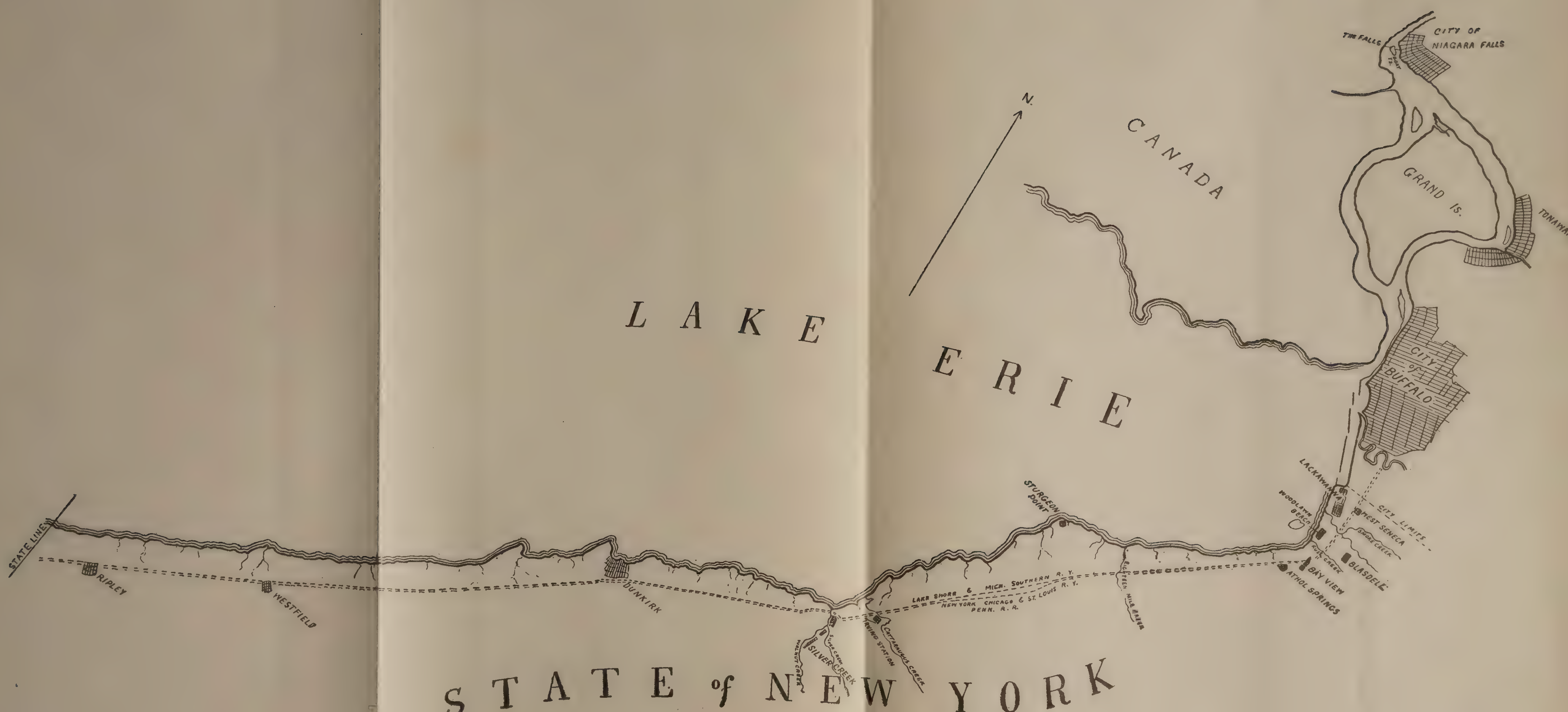
Much valuable time was lost usually by attempting every known scheme for preventing pollution at the intake. Many of these schemes demanded removal of sewage outfalls to a greater distance or sewage disposal of some kind involving serious engineering problems and expenditure of great sums of money.

In almost every instance sewage disposal of some kind was a consummation devoutly to be wished. But the problem and expenditure made its immediate accomplishment impossible. As at Erie and Niagara Falls, the citizens continued to drink sewage-polluted water for years, and eventually filtration plants will have to be installed to prevent water-borne typhoid, while the sewage-disposal problem is still unsolved.

## FILTRATION OF LAKE ERIE WATER.

Filtration of Lake Erie water used as public water supply is inevitable. Not only has the consumer a right to demand a safe drinking water every day in the year, but it is reasonable that he demand, also, a water which is clear, sparkling, and attractive.

Treatment of a clear water with hypochlorite of lime or other methods is capable of rendering the treated water safe. However, such treatment does not remove the turbidity in roily waters, and there is a growing sentiment for filtration methods which not only furnish a safe water but also remove the objectionable turbidity.




MAP 1.—The New York shore of Lake Erie and the Niagara River.

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### SEWAGE POLLUTION OF LAKE ERIE.

Sewage pollution of Lake Erie must be controlled. The zone of polluted water should be lessened and not widened. No crude sewage should be discharged into the lake without treatment. Existing faulty sewer systems should be eliminated as rapidly as engineering and economic problems connected with the change can be solved. Inasmuch as the development of these sewer systems has extended over a great number of years and their existence to-day represents capital invested, their elimination will be correspondingly slow. In the meantime cities taking their water supplies from the Niagara River or from Lake Erie should by filtration, treatment, or both, render those supplies safe for drinking purposes.

### THE NEW YORK SHORE OF LAKE ERIE AND THE NIAGARA RIVER.

In considering the question of the pollution of the eastern end of Lake Erie and of the Niagara River, it is necessary, first, to estimate roughly the amount and character of this pollution. It will also be necessary to consider the relative positions of sewer outfalls, polluted streams, and waterworks intakes.

The territory covered will be divided as follows:

1. The lake shore from the New York State line to the city of Dunkirk.
2. The city of Dunkirk.
3. The lake shore from the city of Dunkirk to the city of Buffalo.
4. The city of Buffalo.
5. The cities of Tonawanda and North Tonawanda.
6. The city of Niagara Falls.

Between the Pennsylvania boundary and the city of Dunkirk Lake Erie receives the water of numerous creeks. These are usually short and torrential in character. The largest and most important are Chautauqua Creek and Canadaway Creek. Chautauqua Creek runs through the village of Westfield, which has a population of about 3,000. Chautauqua Creek has a considerable drainage area and in flood times carries a great deal of farm and roadside drainage.

Canadaway Creek is of more importance because of its carrying the sewage of the town of Fredonia and having an outlet uncomfortably near the waterworks intake of the city of Dunkirk. Ripley (population 1,000) and other small places in this area are insignificant and a negligible quantity in the matter of lake pollution.

### THE CITY OF DUNKIRK.

This city has a population of about 18,000. It depends largely upon the American Locomotive Works for its prosperity and is essentially a manufacturing city. Three large creeks enter the lake

at or near Dunkirk, the most westerly, Canadaway Creek, carrying the sewage of Fredonia (population 6,000) to the lake at a point within 1½ miles of Dunkirk's waterworks intake. The other two creeks carry considerable sewage to the harbor.

The sewers are on the combined system and discharge into the harbor at the foot of the streets running north and south. There are about 20 outlets, ranging in size from a 12-inch pipe to a 48-inch stone sewer. The entire sewage of the city, probably 2,000,000 cubic feet daily, is poured into this shallow harbor, which is estimated to contain not more than 100,000,000 cubic feet of water. The excessively polluted water is carried out of the harbor entrance and, given certain abnormal conditions of wind, could readily reach the waterworks intake.

The accompanying map shows the sewage-polluted harbor of Dunkirk, the position of the waterworks intake, and the proximity of Canadaway Creek, laden with Fredonia's sewage.

That portion of Lake Erie from the city of Dunkirk to the Buffalo city line receives numerous creeks, and upon this shore line are several towns and villages of importance from the standpoint of lake pollution. About 10 miles northeast of Dunkirk, Silver Creek and Walnut Creek discharge into the lake by a common mouth. At this point is situated the village of Silver Creek, with a population of 2,500. Walnut and Silver Creeks drain a combined area of about 59 square miles. There are no towns or villages above Silver Creek contributing sewage in any considerable amount to these streams.

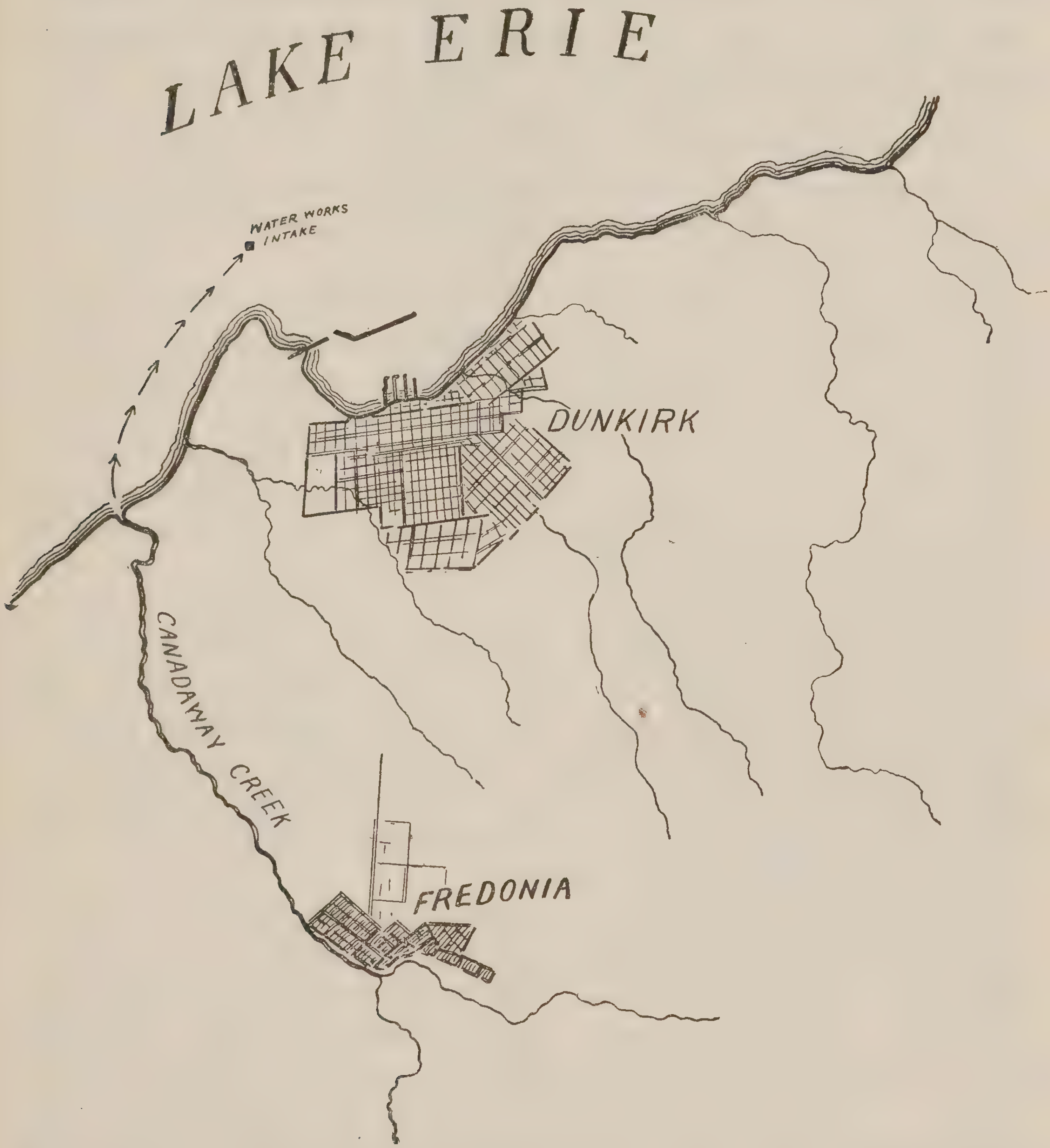
The sewage of Silver Creek will be cared for according to plans approved by the State board of health. These plans provide for screening and septic tank treatment, with some form of treatment of the effluent to be carried out later. Provisional authority was granted, February, 1908, by the New York State Board of Health to discharge the effluent from the screening plant into Silver Creek without further treatment for the present.

Silver Creek takes its water supply from Lake Erie. The intake is located near the mouth of Silver Creek and a little to the west.

Cattaraugus Creek rises in Wyoming County and flows west into Lake Erie. It has a watershed of about 560 square miles. Its watershed is hilly and contains some of the highest ground and the greater part of the forest area existing in the western part of the State. The watershed is rather sparsely populated, but the development of the waterpower means increased population and an increasing amount of pollution carried to Lake Erie by this stream.

Hamburg has a population of about 2,000, and is situated upon Lake Erie and Eighteen Mile Creek, 20 miles south of Buffalo. The State board of health approved plans for sewage disposal, September, 1908. This system provides for settling tanks (8-hour retention),

and discharge of the effluent into Eighteen Mile Creek. Hamburg gets its water supply from two wells. One of these is a well 20 feet deep, furnishing satisfactory water. The other, located outside the village, furnishes a highly sulphuretted ground water, aerated to get rid of the odor, and filtered mechanically after treatment with alum. An analysis of this water made by the State hygienic




MAP 2.—The city of Dunkirk, showing position of water works intake and course of polluted water from Canadaway Creek.

laboratory showed a low bacterial count and absence of *B. coli.* The raw water seemed to be as good as the filtered sample.

Northeast of Hamburg on the lake shore drainage area are situated Athol Springs, Bay View, Woodlawn Beach, Blasdell, and the industrial towns of West Seneca and Lackawanna. The pollution from the last two is the most important.

Lackawanna has a population of 11.300 and West Seneca about the same. They are busy industrial towns and contribute considerable quantities of sewage pollution to Lake Erie through the medium of Smoke Creek.

Smoke or Smoke's Creek enters the lake within the town limits of Lackawanna, and within about 1½ miles of the Buffalo city line. Smoke Creek has been considered a serious menace to Buffalo's water supply. It was at first supposed that the sewage-laden water from Smoke Creek passed directly northward with the main current of Lake Erie into the Niagara River, and would thus pass over the waterworks intake located about the center of the Niagara River. As typhoid was epidemic in 1903 among the laborers in Lackawanna, the menace from Smoke Creek caused considerable excitement in Buffalo at that time.

Dr. George E. Fell,[1] of Buffalo, however, showed by a series of interesting experiments that, due to "fortuitous circumstances" rather than as a result of scientific study, the Buffalo intake had been placed where there was no danger of contamination from Smoke Creek reaching it. He traced the currents by means of floats, and showed that the current from Smoke Creek did not proceed north directly to the entrance of the Niagara River, but that the water from Smoke Creek, upon reaching a point opposite the southern entrance to Buffalo Harbor, was deflected almost at right angles and carried by the normal lake current through the opening between the breakwaters to the inner harbor. The action of the currents, according to Dr. Fell, is best indicated by diagram. He showed further that polluted water upon leaving the harbor divided, one portion continuing into Black Rock Harbor and the other passing outside Bird Island Pier, and closely hugging the pier, without merging with the central lake current which heads for the intake.

The fortuitous circumstances described by Dr. Fell seem to be a rather insecure means of protection for the intake, and it is not difficult to conceive of abnormal conditions which would remove this measure of protection entirely. It is a well-known fact that gales blowing continuously from the southwest cause the water in Buffalo Harbor to rise as much as 7 feet, and that gales blowing for days from the northeast cause a drop below the normal of 6 feet. Such conditions may produce currents entirely at variance with Dr. Fell's observations. Unfortunately, accurate study by means of floats in such times of storm is difficult if not impossible. The intake referred to above will be changed in the near future, and the new intake will be described later in connection with the city of Buffalo.

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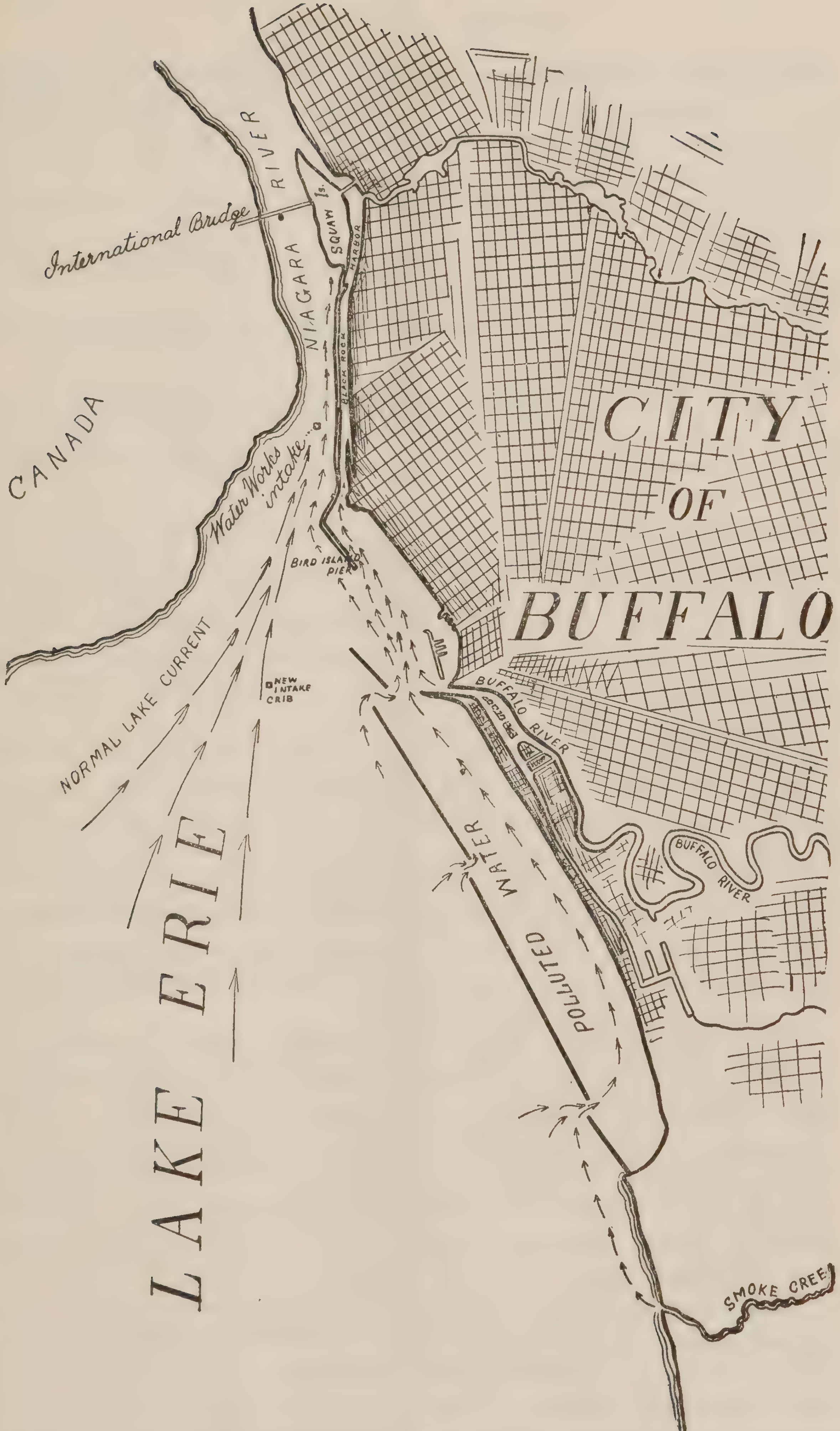
[1] Fell, Geo. E., M. D., "The currents at the easterly end of Lake Erie and head of Niagara River."—Journal American Medical Association, Vol. LV, Sept. 3, 1910, p. 828.




MAP 3.—Currents of Lake Erie at Buffalo under normal conditions, according to Dr. Fell, the waterworks intake is protected by these currents.

THE CITY OF BUFFALO.

Buffalo has a population of about 425,000. Its sewage is discharged into the Niagara River by means of four principal outlets, Hertel Avenue sewer, Bird Avenue sewer, Swan Street trunk sewer, and Buffalo River.

The position of these sewer outlets is shown by the accompanying map of Buffalo.

The Hertel Avenue sewer has a diameter of 5 feet at its point of discharge into the Niagara River.

The Bird Avenue sewer discharges into Black Rock Harbor, and is 8 feet in diameter.

The Swan Street intercepting trunk sewer has a diameter of 8 feet 6 inches at the outfall, which passes under the Erie Canal to discharge into the Niagara River, a considerable distance below the old intake of the waterworks.

The Buffalo River and its tributary, Cazenovia Creek, receives the sewage from the southern portion of the city and discharges into Buffalo Harbor. These, with another tributary, Cayuga Creek, drain a large and populous area in addition to the southern portion of the city of Buffalo, and in time of flood are said to deliver as much as 20,000 cubic feet per second, or nearly one-tenth of the volume of the Niagara River itself.

*Sewers draining into Niagara River.*—Hertel Avenue at Cornelius Creek, 5 feet diameter, iron pipe; Swan Street trunk sewer, opposite Albany Street, 8½ feet diameter, brick; Bird Avenue sewer, 8 feet diameter, brick. This sewer now drains into Erie Canal; the dry weather flow was formerly carried through a 4-foot diameter sewer alongside the canal, from Bird Avenue to the Swan Street trunk sewer at Albany Street. It was almost destroyed when the canal improvement was made. It is contemplated to rebuild it or construct another sewer on practically the same lines.

*Sewers draining into Buffalo River.*—Main Street, west side, 36 inches diameter, brick; Main Street, east side, 24 inches diameter, brick; Washington Street, 15 inches diameter, tile; Indiana Street, 24 inches diameter, brick; Illinois Street, 30 inches diameter, brick. The dry-weather flow of the above five sewers will be intercepted and pumped to the Swan Street trunk sewer; Michigan Street, 24 inches diameter, brick; Cincinnati Street, 24 inches diameter, brick; South Michigan Street, 12 inches diameter, tile; South Street, 22 by 15 inches diameter, tile; Louisiana street, 24 inches diameter, brick; Ganson Street, 15 inches diameter, tile; Hamburg Street, 36 inches diameter, brick; Fitzgerald Street (extended), 22 by 15 inches diameter, tile; Smith Street, 48 inches diameter, brick; Abbott Road, north side, 10 inches diameter, tile; Abbott Road, south side, 10


MAP 4.—City of Buffalo, showing sewer outlets. The entire sewage goes into Buffalo Harbor and the Niagara River through three main trunk sewers and the Buffalo River.

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inches diameter, tile; Abbott Road, north side, 20 inches diameter, tile; Abbott Road, south side, 20 inches diameter, tile; Maurice Street, 8 inches diameter, tile; Orlando Street, 8 inches diameter, tile; Babcock Street, 72 inches diameter, brick (overflow); Bailey Avenue, 8¾ inches diameter, brick (overflow); Heussy Avenue, 12 inches diameter, tile; Kimmel Avenue, 18 inches diameter, tile.

*Sewers draining into Cazenovia Creek.*—South Park Avenue, west side, 24 inches diameter, brick; South Park Avenue, east side, 10 inches diameter, tile; South Park Avenue, east side, 10 inches diameter, tile; Unger Avenue, east side, 10 inches diameter, tile; Mumford Avenue, 63 inches diameter, brick; Hammerschmidt Avenue, 12 inches diameter, tile; Ryan Street, west side, 10 inches diameter, tile; Ryan Street, east side, 10 inches diameter, tile; Geary Street, east side, 10 inches diameter, tile; Menden Street, 78 inches diameter, brick.

The entire untreated sewage of the city of Buffalo is discharged by these various outlets into the Niagara River. The three sewer outlets are well above the old intake, and as shown by Dr. Fell, currents, at least under normal conditions, protected this old intake against the contaminated water of Buffalo River and Smoke Creek. However, the municipalities of Tonawanda, North Tonawanda, Lockport, and Niagara Falls take their water supply from the Niagara River at points below the outfalls of Buffalo's sewers. The consumption of water in Buffalo is enormous, and as a consequence the sewage probably measures 375 gallons per capita daily, or about 160,000,000 gallons daily.

The public water supply of the city of Buffalo is taken from the Niagara River at a point 1,000 feet offshore, in 16 feet of water. This system was completed in 1874, but was not in exclusive use until 1894.

Previous to 1894 Buffalo took a part of its water supply from the Niagara River, comparatively near the shore at the Bird Island Pier. The shore water has always been grossly polluted and typhoid rates were high. In 1894 the Bird Island Pier intake was closed and water taken exclusively from the intake farther out. This is the intake referred to above as protected by "fortuitous circumstances," and from which water is still being taken.

Coincident with the closure of the Bird Island Pier intake, the typhoid rate dropped as follows:

*Typhoid death rate per 100,000.*

| | |
|---|---|
| 1894 | 62 |
| 1895 | 28 |
| 1896 | 22 |
| 1897 | 19 |

That this intake is protected from contamination by the water from Buffalo River and Smoke Creek, as claimed by Dr. Fell, is probably true for the major portion of the year. However, a considerable portion of the polluted water from Buffalo Harbor passes outside Bird Island Pier, between that structure and the intake, every day in the year. The distance between the Bird Island Pier and the intake is 700 feet. Analyses of the water indicate that in good weather fecal pollution extends to 300 feet or more from the pier, and toward the intake, nearly half the total distance. In times of flood and under certain storm conditions the sewage contamination without doubt approaches nearer the intake, and may pass over and beyond it.

The intake pier is connected with the suction wells at the pumping station by two tunnels. These tunnels pass under Black Rock Harbor, the Erie Canal, and the main intercepting sewer of the city. They are cut through rock, and are unlined. This is significant in view of the fact that fissures and seams were encountered in the rock during construction.

SOURCES OF POLLUTION OF BUFFALO'S WATER SUPPLY.

The possibility of leakage through unlined tunnels must be considered, and can only be determined by comparative tests at the intake and at the pumping station.

In regard to pollution from distant cities, it must be borne in mind that Lake Erie is comparatively shallow, and that contamination of Buffalo water is theoretically possible from Dunkirk (37 miles), Erie (80 miles), and Cleveland (174 miles).

It is certain that the shore water all along the lake is grossly polluted. This shore pollution does not flow in a steady current in one direction, but tends to oscillate back and forth, by the action of changing winds and currents, allowing diffusion of the contaminating material, with dilution and sedimentation. The time required for infected material to travel from Cleveland to Buffalo (174 miles), even if the material reached the principal current, is much greater than the time required to travel the same distance in a river or stream.

The volume of water available for dilution is enormous, and very much greater than that found in an ordinary river. From these facts, and the experience of Jordan, Russell, and Zeit with Chicago's sewage,[1] the possibility of pathogenic organisms from sewage of Cleveland, or even of Erie and Dunkirk, reaching Buffalo must be very remote. However, further investigation of Lake Erie water must be made before rendering a positive opinion on this point. The pollu-

[1] Jordan, E. O., Russell, H. L., and Zeit, F. R., "The longevity of the typhoid bacillus in water." Journal of Infectious Diseases, Vol. I, No. 4, Nov. 5, 1904, p. 641.

tion from passing vessels is a possibility which exists during the navigation season and should be prevented.

With regard to Buffalo's old intake, which is still being used, it is not necessary to look for remote possibilities of contamination. The ever present possibility of contamination from the Buffalo River is a ready explanation of the frequent high bacterial counts and the presence of *B. coli* in small samples of Buffalo water. Whatever may have been the avenue of infection, there is no doubt of the contamination of the Buffalo water supply at times. Analyses made of tap water by Dr. Bissell,[1] city bacteriologist, almost daily during the calendar year of 1909 repeatedly showed colon in 1 cubic centimeter samples, and showed bacterial counts frequently above 1,000 per cubic centimeter.

The new intake is situated in what is known as Emerald Channel, on the eastern side of Horseshoe Reef, at the outlet of Lake Erie. Water will be taken exclusively from this intake during the present year. The tunnel from the new intake is also unlined. No opinion can be given as to the existence of contamination by seepage until the new plant has been in operation, when a comparative test of water at the intake with water at the pumping station will show the existence or absence of such contamination.

Buffalo's new intake is in grave danger of pollution from Buffalo Harbor under certain storm conditions.

Strong southwest winds or gales blowing for many hours may raise the water in Buffalo Harbor 6 or 7 feet above normal. The same conditions produce a drop in the water at Amherstburg of 5 feet or over, so that under these conditions the lake surface from southwest to northeast is an inclined plane about 12 feet higher at Buffalo than at Amerherstburg. This rise at Buffalo due to piling up of the water is followed by a drop of over 6 feet in Buffalo Harbor within a few hours.

This drop is occasioned by the return of this mass of water toward the southwest to equalize the lake level. Inasmuch as this rapid fall in the water is accomplished frequently in spite of continuance of a southwest wind, the bulk of the water returns toward the southwest by means of an undercurrent. This undercurrent scours out the sludge accumulations from Buffalo Harbor while the surface current is still setting toward the Buffalo docks. The velocity of this undertow is considerable, and can be imagined if one considers that this enormous bulk of water is delivered toward the center of the lake through the comparatively narrow openings between the breakwaters within a very few hours.

Let us consider an instance of what may happen under conditions as shown on Chart XXXVIII, taken from Fluctuations of Water of

[1] Annual report department of health, city of Buffalo, 1909, p. 46.

Lake Erie, by Alfred J. Henry, professor of meterology, and furnished the writer by Mr. G. R. Oberholtzer, local forecaster, United States Weather Bureau, Erie, Pa.

On November 21, 1900, a gale from the southwest produced a rise in Buffalo Harbor of 8 feet 4 inches above zero and a corresponding fall of 2 feet 9 inches below zero at Amherstburg, zero being 570


MAP 5.—Currents at Buffalo under conditions produced by southwest gales. In spite of the wind persisting and a surface current toward Buffalo produced thereby, there takes place a sudden drop of several feet in the harbor level. The enormous volume of water escapes from the harbor openings as an undercurrent in the direction indicated by the arrows. This current would not be affected by the normal lake current setting north until after it had passed over and beyond the intake.

feet above sea level; 572.8 represents the mean level of Lake Erie. This rise was followed by a sudden drop in the level of Buffalo Harbor of 7 feet 6 inches in four hours without change in the direction of the wind. Roughly, seven times the surface area of Buffalo Harbor would represent in terms of cubic feet the amount of water which was discharged from Buffalo Harbor in four hours on this occasion. There is every reason to believe that a great part of

this water passes out of the harbor entrances around both ends of the north breakwater, and as the compensatory undertow for the equalization of the lake level is of necessity toward the southwest, this polluted water is swept toward the site of the new intake, as indicated in the diagram.

How far this current toward the intake may be modified by the normal lake current setting toward Niagara Falls can only be demonstrated by float observations during these storm conditions. Needless to say such observations are extremely difficult, if not impossible.

The main channel through which passes the bulk of the water from Lake Erie to the Niagara River lies to the westward of the new intake, so that the modifying influence of this current on the direction of the undertow from Buffalo Harbor would not be exerted until after the polluted water had passed over the intake.

Analyses made at the new intake by Mr. Theodore Horton, C. E., chief engineer New York State Board of Health, indicate a very good water, low bacterial count, and absence of *B. coli*. It must be admitted, however, that the examinations were not made daily for a considerable length of time, and further examinations daily for long periods must be made before drawing positive conclusions.

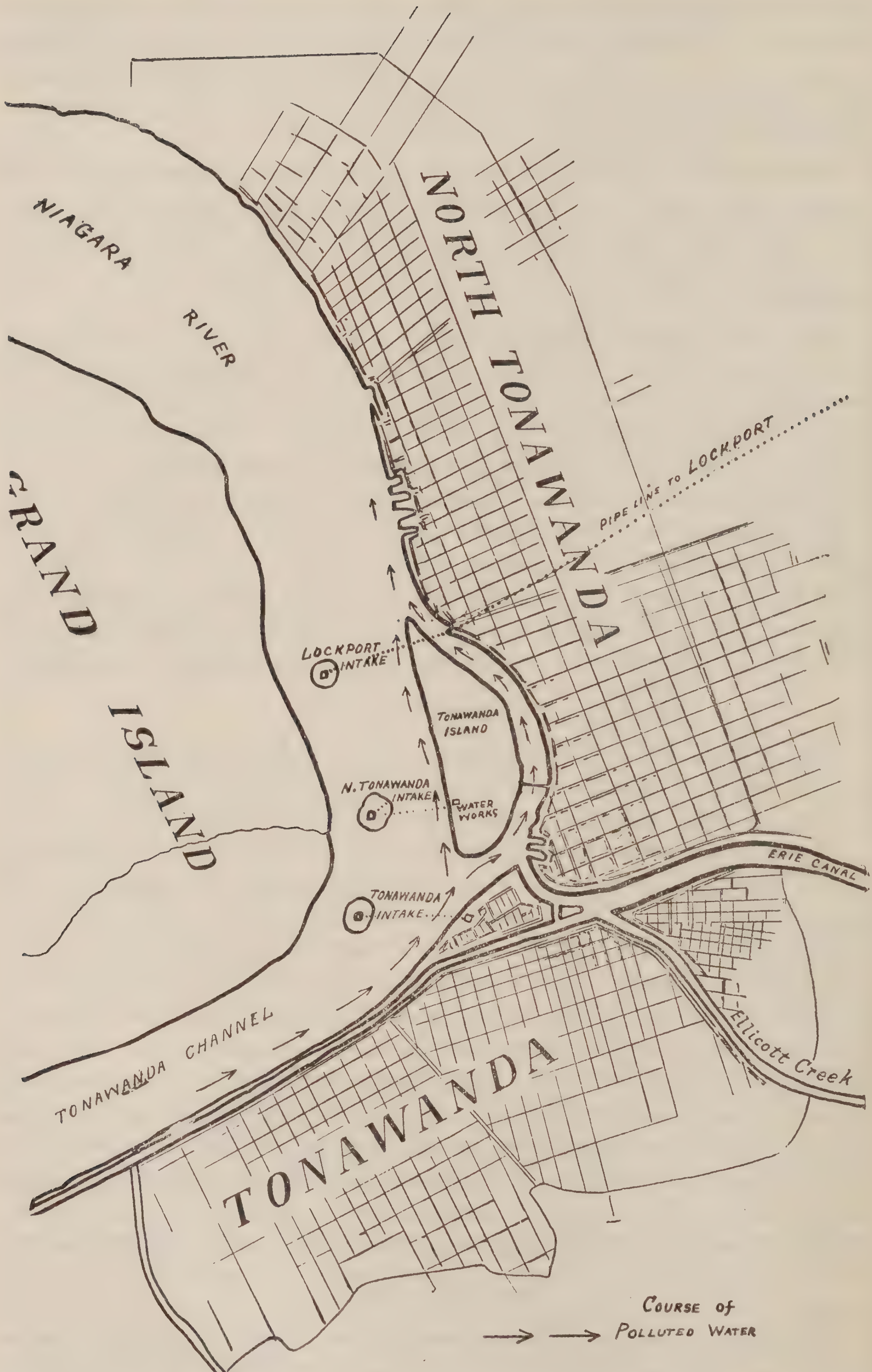
### THE TONAWANDAS.

Tonawanda has a population of about 7,500 and North Tonawanda about 11,000, a combined population of over 18,000. The sewage of these towns ultimately goes into the Niagara River.

The North Tonawanda sewage goes directly into the Niagara River through five outfalls, with a total discharge of about 4,500,000 gallons per day. The waterworks intake for North Tonawanda is located well over toward the Grand Island shore and 1,400 feet from Tonawanda Island. The intakes for Tonawanda and Lockport, situated, respectively, above and below the North Tonawanda intake, are also placed well over toward the Grand Island shore. The accompanying map shows the location of the intakes. These intakes do not furnish a safe water except under ideal conditions, and at certain times the water is undoubtedly badly polluted. The only thing that can be said in favor of these intakes is that their position is infinitely better than if placed near the Tonawanda or eastern shore, where the water is grossly polluted and is really dilute sewage.

### NIAGARA FALLS.

The city of Niagara Falls covers an area of about 10 square miles and has a population of 30,445 (census of 1910). During June, July, August, and September the population is augmented by the addition of from 5,000 to 15,000 visitors daily.




MAP 6.—Cities of Tonawanda and North Tonawanda showing position of waterworks' intakes for the Tonawandas and Lockport. The arrows indicate the course of the polluted water "hugging" the shore under normal weather conditions.

The sewer system is of the combined type, with about 1,200 catch basins for storm-water collection and about 7,000 house connections to conduct the house wastes into the mains. The sewers have a total length of about 72½ miles, and all outlets enter the Niagara River below the Falls.

The city collects about 10,000 tons of garbage and refuse yearly. The collection of ashes is separate, and the clean ashes are used for filling and upon unpaved streets. All garbage and refuse is dumped into the Niagara River through a steel chute at the foot of Bath Avenue.

There are two sources of water supply for Niagara Falls—the municipal supply and the Niagara Falls Waterworks Co. The municipality supplies the northern portion of the city and the Niagara Falls Water Co. supplies the southern or business section of the city. The municipal supply is taken from the hydraulic canal, and is pumped unfiltered into the mains. A rectangular well 24 feet square adjoining the canal receives the water direct. The well is cleaned once in three months and about 1,000 cubic feet of material removed. This well during the cleaning process is said to emit a stench which is almost unbearable.

The Niagara Falls Water Co. supply is taken also from the hydraulic canal. From a well 8 feet square it is pumped to a settling basin. It is filtered through mechanical Morrison-Jewell filters. Analyses seem to show that the filters remove little more than the matters in suspension.

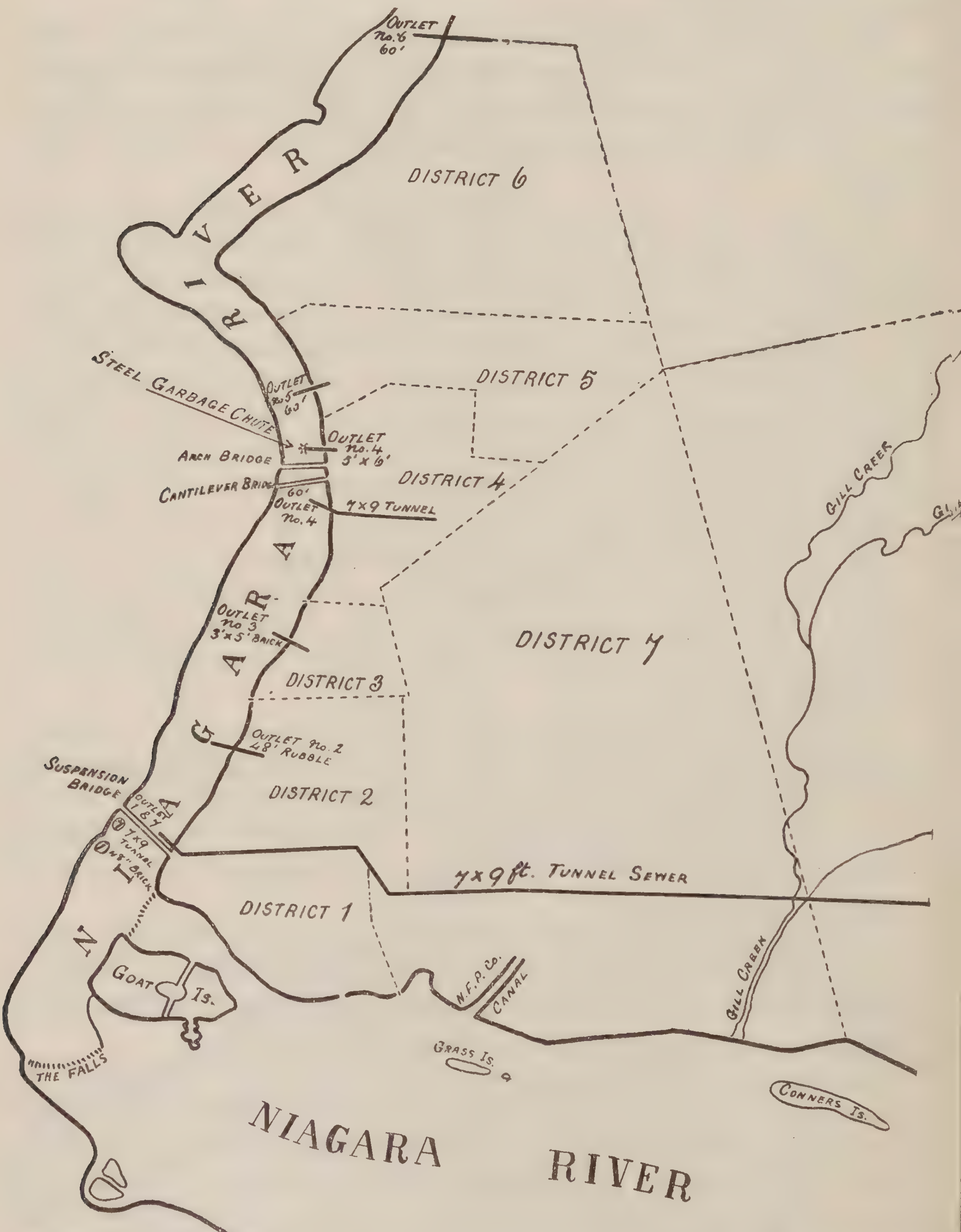
The source of both these supplies is the same. The hydraulic canal is fed from the water of the Niagara River at the American shore. The city of Buffalo, 16 miles above, discharges 160,000,000 gallons of sewage daily into the river. The velocity of the Niagara River prevents sedimentation, and carries contamination very quickly a distance of 16 miles.

Dr. Horton, city bacteriologist of Niagara Falls, examined water from the municipal water supply daily from October 21, 1910, to January 1, 1911. The lowest bacterial count was 3,100 per cubic centimeter, and counts reached as high as 36,000.

The intakes of the Tonawandas and Lockport, further out in the stream, are very much better placed than the Niagara Falls intake. The sewage-polluted water is known to "hug the shore," as shown in analyses made by Dr. Bissell, city bacteriologist of Buffalo, in 1904, and by Mr. Theodore Horton in 1907.[1] At Buckhorn Island a sample of water showed a bacterial count of 800 per cubic centimeter; 300 yards from the American shore the count was 860 per cubic centimeter; 100 yards from shore the count was 10,000, and directly offshore there were too many to count.

[1] Horton, Theodore, Twenty-eighth Annual Report New York State Board of Health, 1907, pp. 713, 714.

The city of Niagara Falls in 1908 finally decided to put in a filtration plant, and to take the water from an intake crib placed 1,500 feet from shore. The plant is now nearing completion. The system is rapid-sand filtration, or, more properly, mechanical filtration, with




MAP 7.—City of Niagara Falls showing sewer outlets and garbage chute. Niagara Falls water supply is drawn from the N. F. Power Co. canal. The new intake will be 1,500 feet off shore.

the use of a coagulant, and provision for the additional use of hypochlorite of lime, if necessary. In the meantime the people have been advised to boil their water. Some are doing so and some are using bottled waters.

## GEOGRAPHICAL DISTRIBUTION OF TYPHOID FEVER IN THE STATE OF NEW YORK.

In cities of New York State with good water supplies the typhoid death rate is low, as shown by the following:

| Cities. | Rate per 100,000 of population. | |
|---|---|---|
| | 1909 | Average for 10 years. |
| New York | 12.7 | 17.0 |
| Rochester | 8.6 | 13.7 |
| Syracuse | 11.1 | 14.8 |
| Binghamton | 13.1 | 20.9 |
| Utica | 15.8 | 17.3 |
| Olean | 11.1 | 18.5 |
| Amsterdam | 11.9 | 18.6 |
| Johnstown | .0 | 17.1 |

On the other hand, those cities using unfiltered water from contaminated rivers have a high typhoid rate:

| Cities. | Average rate per 100,000 of population for 10 years. | Source of supply. |
|---|---|---|
| Niagara Falls | 129.1 | Niagara River. |
| Cohoes | 83.8 | Mohawk River. |
| Lockport | 51.5 | Erie Canal and recently Niagara River. |
| Oswego | 49.8 | Oswego River. |
| Ogdensburg | 48.5 | Oswegatchie River. |
| North Tonawanda | 34.1 | Niagara River. |
| Tonawanda | 31.5 | Niagara River. |
| Rome | 21.7 | Mohawk River until 1909, now Fish Creek. |

Rome has a relatively lower rate than Cohoes, being situated above Cohoes, on the Mohawk River, where pollution is presumably less.

High typhoid-fever rates, if due to the water supply, depend upon the amount of pollution in such supply and are independent of whether the supply is drawn from lakes, rivers, springs, or wells.

It is impossible to generalize in discussing the use of unfiltered lake water as a supply for cities. For example, Rochester takes its supply from Hemlock Lake. Analyses show this lake water to be a safe drinking water, and, as might be expected, Rochester's typhoid rate is very low. On the other hand, Dunkirk, using unfiltered Lake Erie water from an intake, which is at times exposed to pollution from its own and Fredonia's sewage, has had an average typhoid rate for 10 years of 39.5. Buffalo, using Lake Erie water unfiltered, has had a typhoid rate persistently high, an average for 10 years of 27, and only

the fact that the Buffalo intake was at least partly protected from Buffalo sewage by currents and the excellent work of the Buffalo health department have prevented higher rates from prevailing.

In the district covered by this investigation the following cities have had persistently high typhoid fever rates: Buffalo, Dunkirk, Lockport, Tonawanda, North Tonawanda, and Niagara Falls.

The typhoid death rates per 100,000 population are shown in the following table and charts. Charts VIII to XIII, inclusive, show the high typhoid death rates in these six cities compared with the rate for New York State:

| Years. | Dunkirk. | Buffalo. | Lockport. | Tonawanda. | North Tonawanda. | Niagara Falls. |
|---|---|---|---|---|---|---|
| 1898 | 8.9 | 29.4 | 145.7 | 40.7 | 24.3 | 107.9 |
| 1899 | 17.5 | 25.7 | 18.1 | 13.5 | 23.1 | 113.0 |
| 1900 | 51.6 | 25.5 | 18.0 | 13.4 | 11.0 | 123.3 |
| 1901 | 32.4 | 27.4 | 71.5 | 13.3 | 32.3 | 143.7 |
| 1902 | 76.5 | 33.9 | 35.4 | .0 | 10.5 | 148.1 |
| 1903 | 29.0 | 36.2 | 75.7 | 26.0 | 41.1 | 114.0 |
| 1904 | 41.3 | 24.4 | 34.6 | 38.4 | 30.2 | 135.3 |
| 1905 | 39.3 | 24.0 | 51.8 | 25.3 | 39.3 | 184.4 |
| 1906 | 31.4 | 23.6 | 67.6 | 50.6 | 19.3 | 154.5 |
| 1907 | 71.8 | 29.2 | 50.1 | 25.0 | 47.2 | 126.0 |
| 1908 | 11.5 | 20.7 | 55.8 | .......... | 55.7 | 98.0 |
| 1909 | 11.1 | 24.2 | 49.7 | 27.3 | 55.6 | 74.9 |

For 10 consecutive years prior to 1908 the typhoid death rate per 100,000 for Niagara Falls was never below 100. This record is unparalleled among American registration cities with the exception of Pittsburg. In 1908 the rate was 98, and in 1909 a further reduction to 74 was effected, probably because many citizens began the use of boiled or bottled water.

A study of the amount of sewage pollution and the relation of the various intakes thereto will result in separating these cities into two classes as follows:

*Typhoid deaths per 100,000 of population.*

| Cities. | Average for 10 years. |
|---|---|
| *Constant pollution of water supply.* | |
| Niagara Falls | 129.1 |
| Lockport | 51.5 |
| *Occasional or intermittent pollution of water supply.* | |
| Dunkirk | 39.5 |
| Buffalo | 27.0 |
| North Tonawanda | 34.1 |
| Tonawanda | 31.5 |

The typhoid-fever rate is again proportionate to the amount of pollution. Lockport has abandoned the Erie Canal as a water supply

Chart VIII. Typhoid Fever Deaths per 100.000, 1900—1909, Dunkirk, N.Y. Compared with New York State

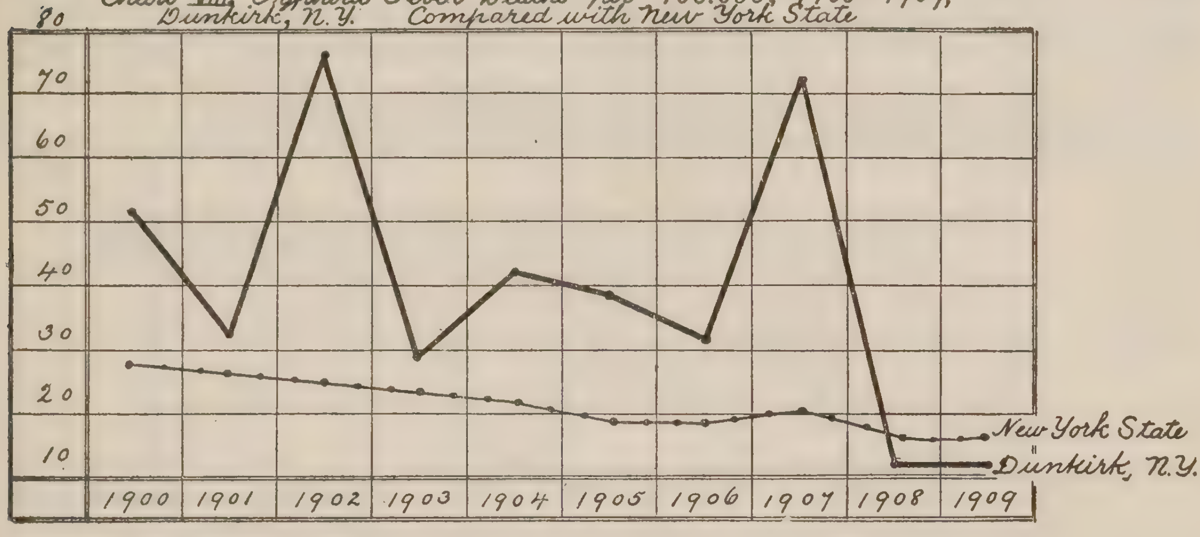



Chart IX. Typhoid Fever. Deaths per 100.000, 1900—1909, Buffalo, N.Y. Compared with New York State.

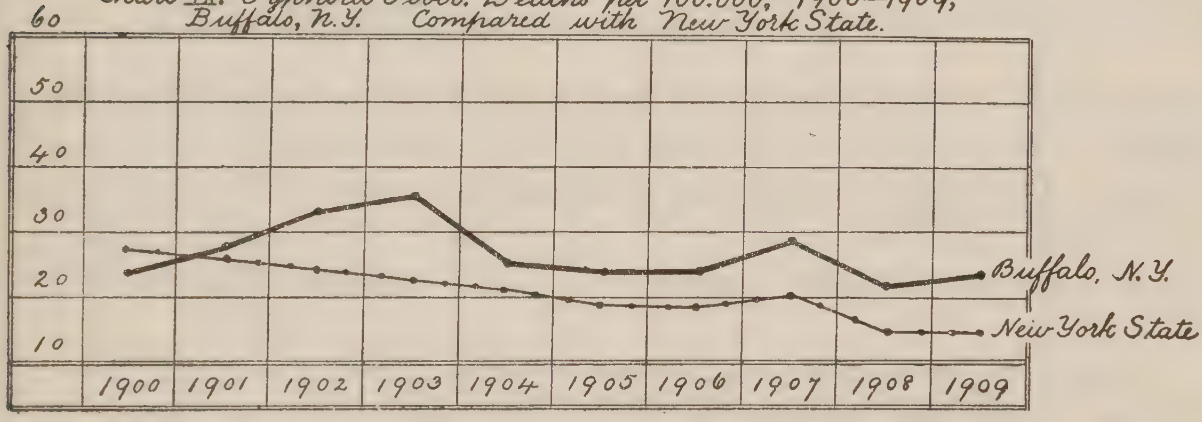
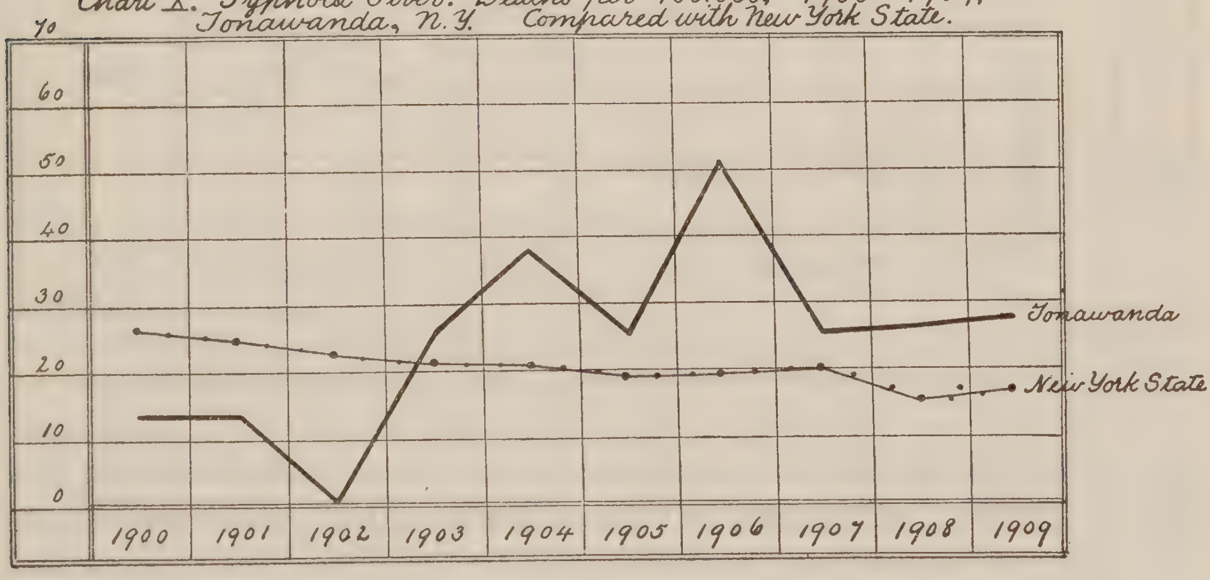


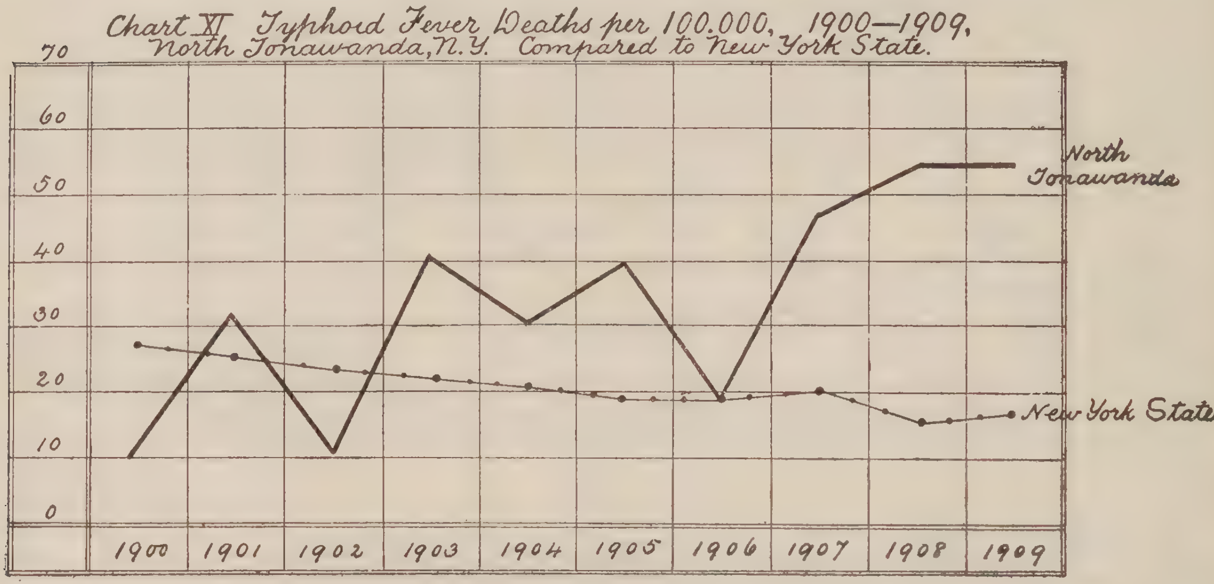

Chart X. Typhoid Fever. Deaths per 100.000, 1900—1909, Tonawanda, N.Y. Compared with New York State.



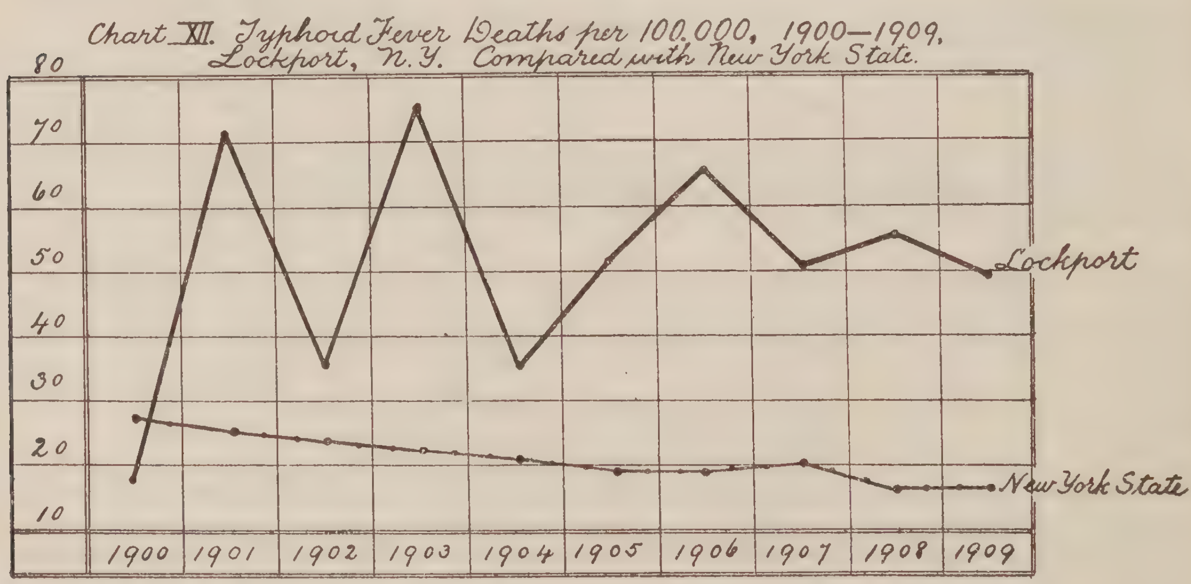

and is now taking water from a new intake in the Niagara River, near those of the Tonawandas, and for this reason Lockport will in the future belong in the second class, with the Tonawandas.

SEASONAL PREVALENCE OF TYPHOID FEVER.

The seasonal prevalence of typhoid fever depends upon factors some of which are not definitely known. It has been demonstrated that the installation of a good water supply markedly influences the



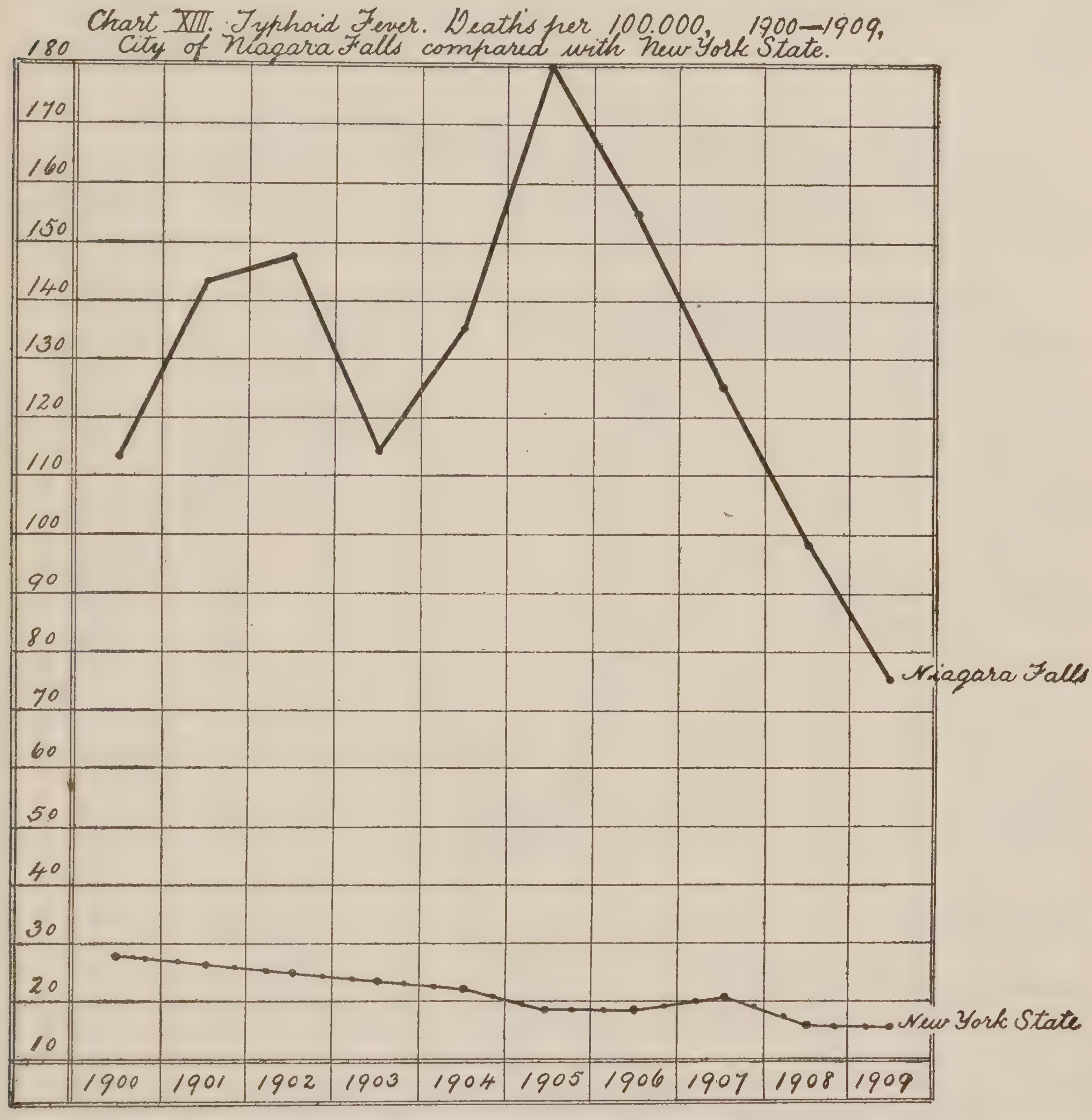

typhoid-fever rate in nearly all towns, and has an especially strong influence in reducing the number of cases which occur in winter and spring. The curve showing the seasonal prevalence of typhoid fever by months in cities with good water supplies is fairly uniform, showing its greatest rise during the typhoid season. The curve for




the whole United States is not so typical, as it includes not only the cities where typical prevalence corresponds to the typhoid months of July, August, September, and October, but also the cities in which a sewage-polluted water supply is a factor, and which show prevalence of the disease in winter and spring. Cities with polluted water supplies show an irregular curve, as these cities are subject to severe

outbreaks in winter and spring, or, in fact, at any time during the year.

The Buffalo department of health has done excellent work not only in the reduction of typhoid fever, but in all other branches of sanitation. The reduction of the typhoid-fever rate has been accomplished in spite of the water supply rather than because of it. Physicians are assisted in making diagnoses by free Widal tests and blood




examinations. This spirit of cooperation encourages the physician to report cases and to take precautions earlier than under other conditions. We know that less than 10 per cent of typhoid cases die, so that theoretically we should have at least 10 cases for every death reported. In practice we find such a ratio rarely, chiefly because in all cities there are cases undiscovered or unreported.

Probably one-half of Buffalo's cases are unreported, as shown by the table following.

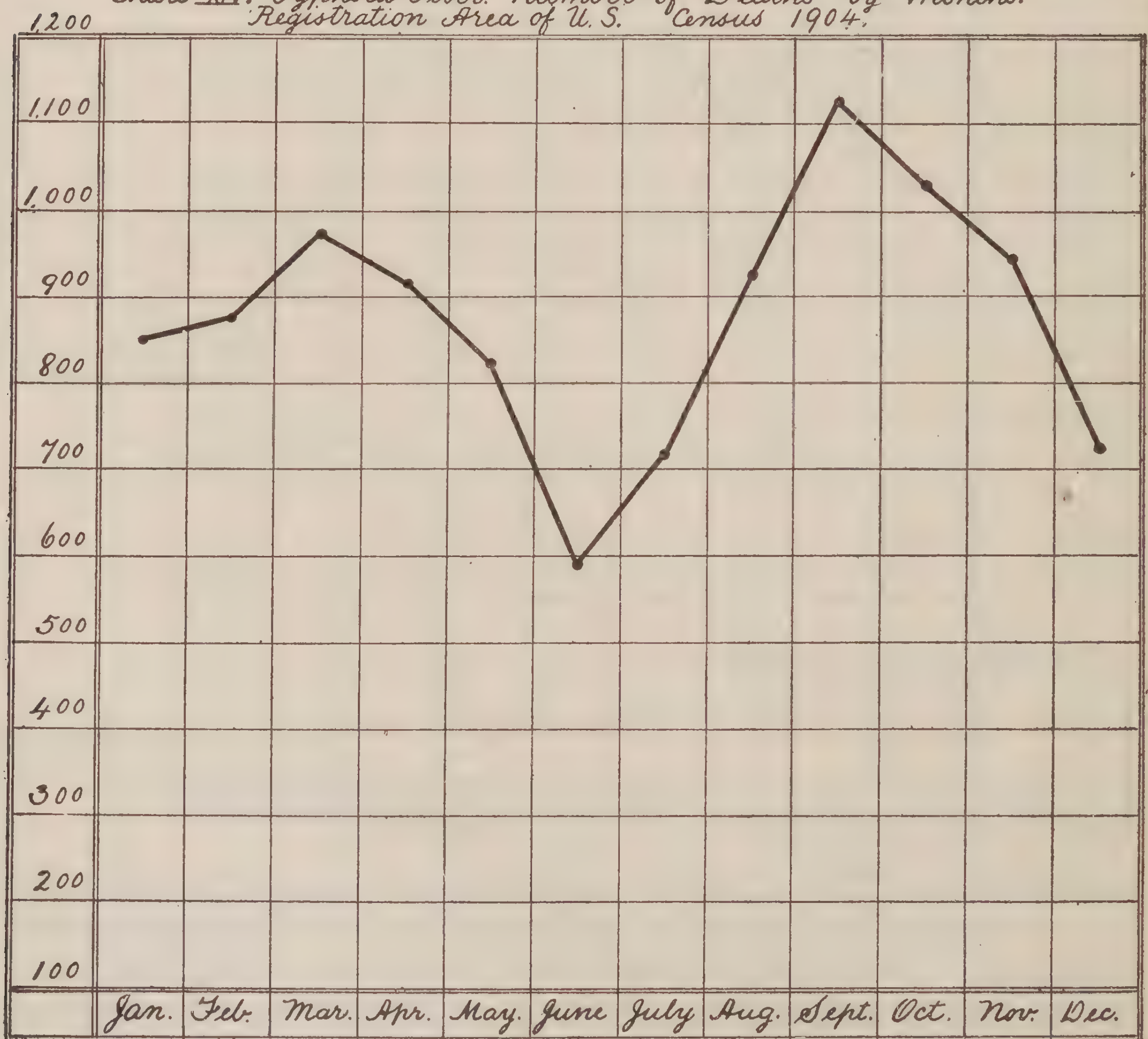
*Typhoid fever report for Buffalo, N. Y., for the year 1910.*

[Population, U. S. census of 1910, 423,715.]

| Month. | Cases. | Deaths. | Month. | Cases. | Deaths. |
|---|---|---|---|---|---|
| January | 31 | 5 | August | 35 | 11 |
| February | 36 | 10 | September | 66 | 5 |
| March | 20 | 2 | October | 55 | 10 |
| April | 27 | 11 | November | 43 | 8 |
| May | 27 | 10 | December | 41 | 8 |
| June | 13 | 2 | | | |
| July | 22 | 4 | Total | 416 | 86 |

For this reason in drawing conclusions from Buffalo statistics it is safer to consider deaths reported than cases reported. Eighty-six deaths were reported in 1910, an average of a little more than 7 per

Chart XIV. Typhoid Fever. Number of Deaths by Months.
Registration Area of U. S. Census 1904.

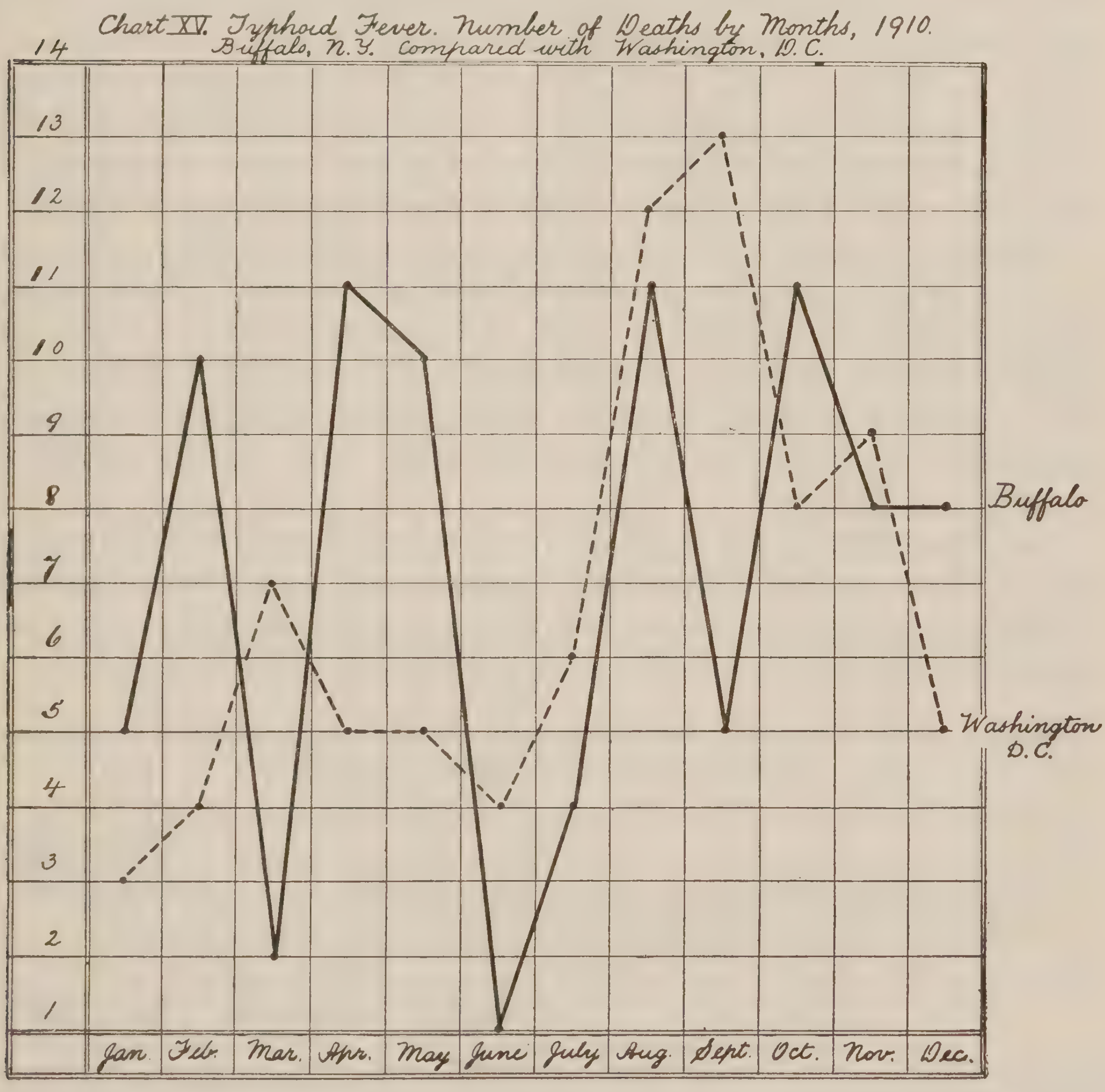



month. There were 11 in August and 10 in October, which are ordinarily classed as typhoid months. High typhoid rates in winter or spring months usually indicate water pollution. There were 10 deaths in February, 11 in April, and 10 in May. The very irregular curve of typhoid in Buffalo is shown diagrammatically below, compared

with the curve of Washington, a city with a high typhoid rate and a good water supply, and with the city of New York, which has a good water supply and a low typhoid rate.

Washington and Buffalo are compared on the basis of deaths per month.

The population of New York City is a little more than 10 times that of Buffalo. Multiplying Buffalo's monthly deaths by 10 gives a fair basis for comparison in seasonal prevalence, and on this basis the accompanying chart is made.




RELATION OF SEWAGE-POLLUTED WATER SUPPLIES TO CHILD MORTALITY AND DIARRHEAL DISEASES.

There seems to exist a relation between polluted water supplies and child mortality. The polluted water may be used to dilute milk, to wash milk bottles, or directly as a beverage. Further, the polluted water supply which causes numerous typhoid cases in cities or towns is responsible indirectly for the contact infections in children resulting from such cases. That many of these occur in children

can not be doubted, even if they remain undiagnosed as typhoid and enter the statistics as diarrhea or enteritis.

The idea that typhoid fever is not a disease of childhood lacks satisfactory evidence to support it. The mere fact that the bulk of the reported cases is made up of adults is not proof. The writer's experience with cholera, an analogous disease epidemiologically, suggests that typhoid, like cholera, may be much more frequent in children than popularly supposed, and that a tendency to light or atypical symptoms in children may be expected.[1] An exhaustive investigation of sick children in cities where typhoid is prevalent would tend to show the real incidence in children.

The subjects of child mortality and diarrheal diseases are indissoluble, as about 89 per cent of all deaths from diarrhea and enteritis occur in children under 5 years of age. Further, nearly 25 per cent of the total deaths under 5 years of age is due to diarrhea and enteritis.

Excessive mortality in children is found in cities of various classes because of the existence of several distinct factors. Cities where many mothers are obliged to work in factories or mills, necessarily neglecting their children, are notorious for high mortality of children. The congested tenement districts, with the accompanying insanitary conditions, are held responsible in our large cities for the excessive mortality of children.

As a rule cities in the State of New York with good water supplies and a low typhoid fever rate have death rates for diarrheal diseases which are not above the average, but, owing to the importance of other factors in some cities, this is not always the case.

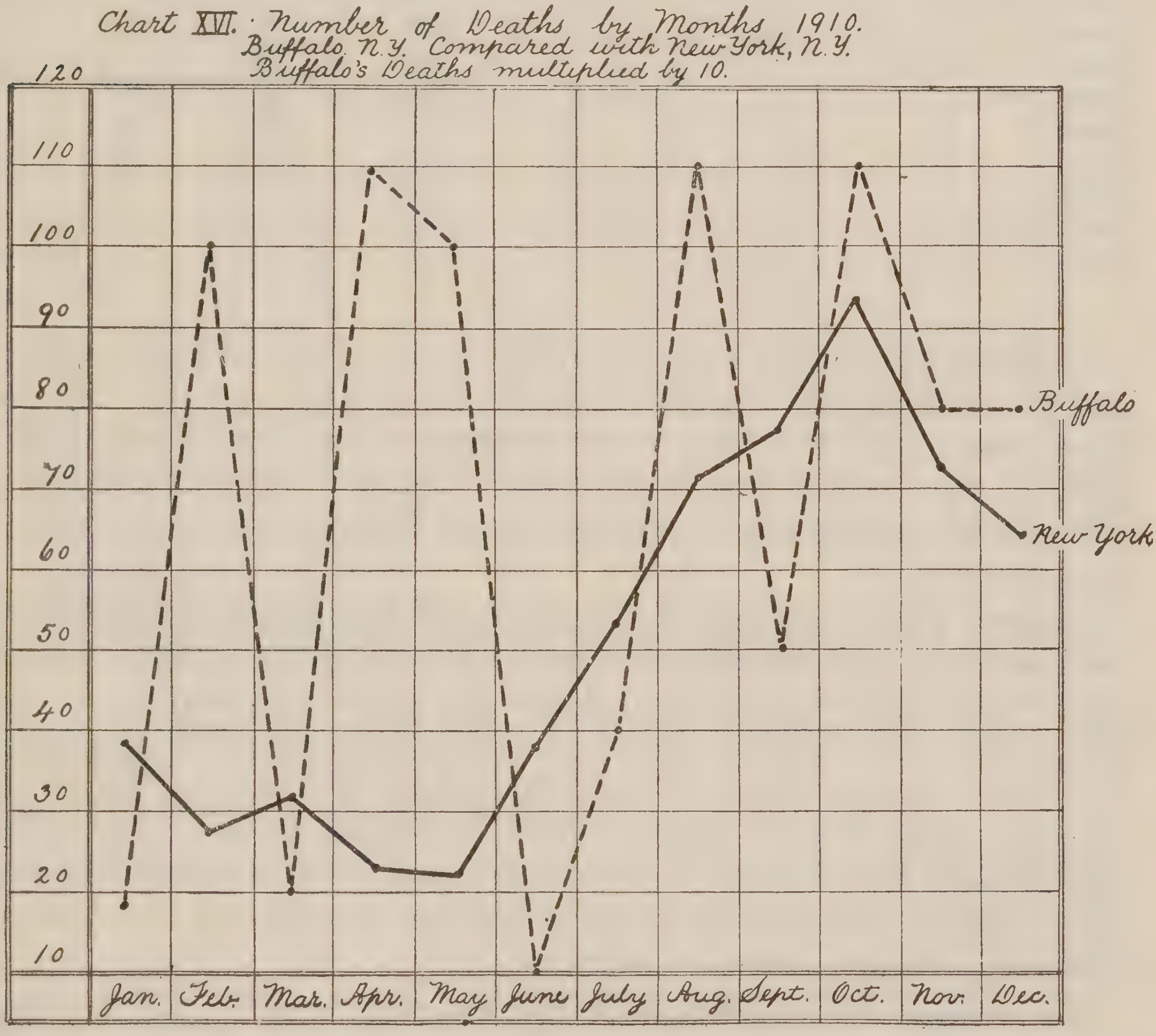
*Diarrhea, enteritis, and child mortality in cities in the State of New York with good water supplies and low typhoid fever rates.*

| Cities. | Deaths per 100,000 of population from— | | Child mortality out of every 100 deaths at all ages in 1909. | |
|---|---|---|---|---|
| | Typhoid fever, average for 10 years. | Diarrhea and enteritis, average for 5 years, 1904–1908. | Under 1 year. | Under 5 years. |
| Registration cities of United States | | 130.5 | 20 | 28 |
| New York | 17.0 | 138.6 | 21 | 33 |
| Rochester | 13.7 | 89.5 | 14 | 22 |
| Syracuse | 14.8 | 105.5 | 21 | 26 |
| Binghamton | 20.9 | 104.7 | 15 | 21 |
| Utica | 17.3 | 133.7 | 22 | 28 |
| Olean | 18.5 | 52.8 | 18 | 25 |
| Amsterdam | 18.6 | 150.7 | 26 | 31 |
| Johnstown | 17.1 | 66.1 | 9 | 13 |

[1] McLaughlin, Allan J., "Some observations upon cholera in children," Philippine Journal of Science, sec. B, 1909, vol. 4, p. 363.

The average number of deaths from diarrhea and enteritis per 100,000 population for the five years 1905 to 1908 in the registration cities of the United States was 130.5. Utica just barely exceeded the average rate, while the New York City rate of 138.6 is low, considering the conditions which exist independent of water supply, and Amsterdam is a typical "mill" town.

The whole subject of the relation of polluted water to the diarrheal diseases of children, including typhoid, needs further experimental




work, but from what is already known the inference is strong that polluted water is responsible for many of these cases.

Cities with polluted or unsafe water supplies have, almost without exception, high death rates for diarrhea and enteritis. That other factors coexist in most cases—overcrowding, neglect of a working mother, etc.—is undeniable, but this does not disprove that a portion at least of this mortality is due to water. In the case of Niagara Falls these other known general factors of child mortality either do not exist or exist in such degree that they seem insufficient in themselves to explain the excessive child mortality.

*Cities in New York State with unsafe water supplies and high typhoid fever rates, also excessive child mortality and high death rate for diarrhea and enteritis.*

| Cities. | Rate per 100,000 of population from— | | Child mortality out of every 100 deaths at all ages in 1909. | |
|---|---|---|---|---|
| | Typhoid fever, average for 10 years. | Diarrhea and enteritis, average for 5 years, 1904–1908. | Under 1 year. | Under 5 years. |
| Registration cities of United States | 30.0 | 130.5 | 20 | 28 |
| Cohoes | 83.8 | 170.9 | 25 | 38 |
| Niagara Falls | 129.1 | 173.2 | 27 | 34 |
| Dunkirk | 39.5 | 126.6 | 24 | 29 |
| Buffalo | 27.0 | 151.6 | 23 | 32 |
| Lockport | 51.5 | 63.7 | 12 | 16 |
| North Tonawanda | 34.1 | 116.0 | 34 | 47 |
| Ogdensburg | 48.5 | 175.0 | 13 | 16 |

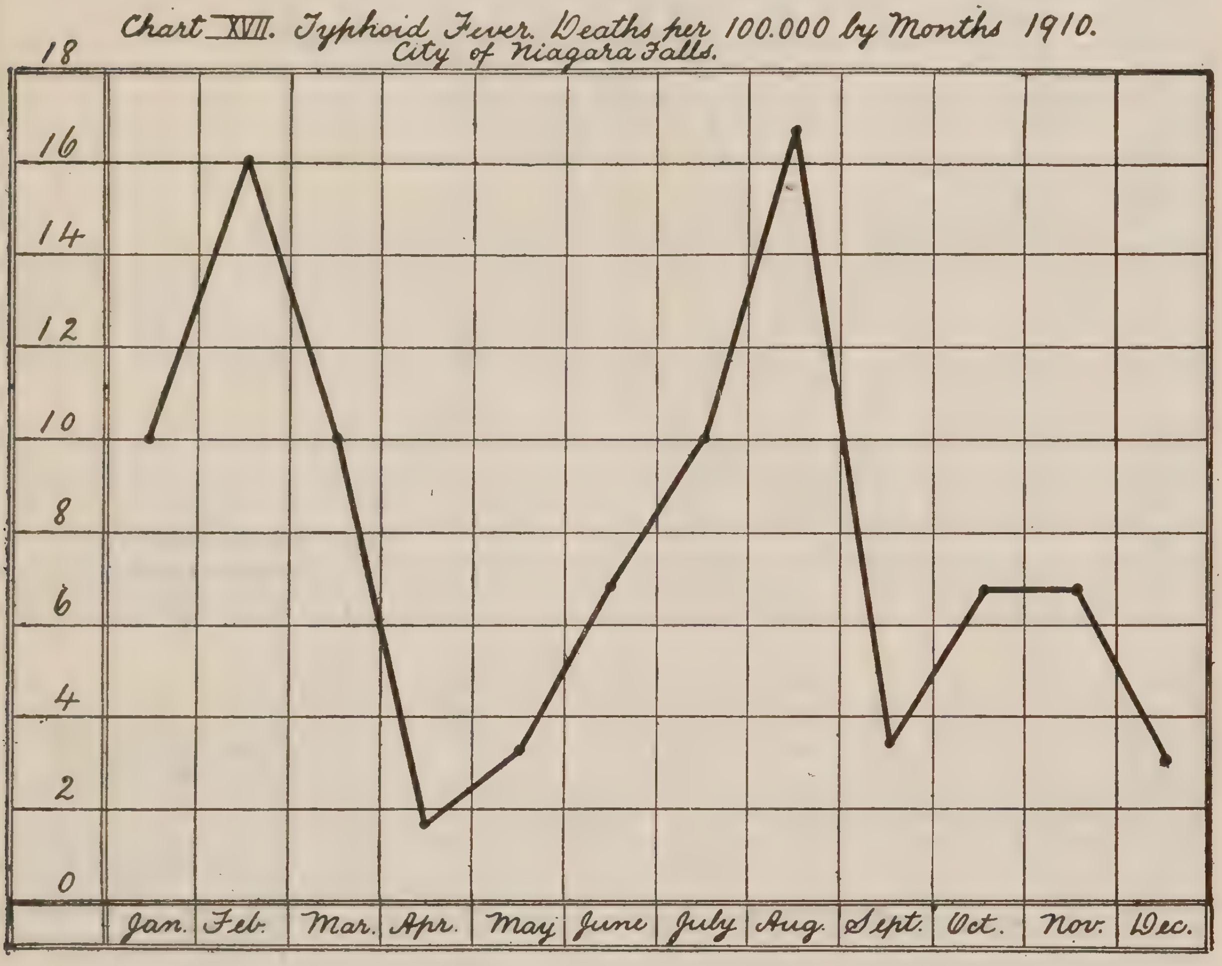
Lockport seems to be the only real exception. North Tonawanda's rate for diarrhea and enteritis is slightly below the average, but the infant and child mortality is the highest in the list. Ogdensburg seems to have had in 1909 a low infant and child mortality rate, but the rate for diarrhea and enteritis is the highest among the towns named above.

Niagara Falls is a city of about 30,000 inhabitants, situated on the east bank of the Niagara River. It owes its prosperity to the great waterfall from which it takes its name. It derives water-power from the Niagara for its factories, and the beauty of the Falls and surroundings attracts thousands of visitors. Baedeker estimates that 400,000 persons visit the Falls yearly. Naturally these people are exposed to whatever danger may exist in Niagara Falls, and, if infected, carry infection to all parts of the United States and foreign countries as well.

The waterpower developed within the city totals 200,000 horse-power. Much of this is transmitted to Buffalo, Lockport, and other places, but enough is retained for the large number of local factories, and these make Niagara Falls rank tenth among American manufacturing cities. In spite of its industrial character, Niagara Falls has no congested tenement-house district. The bulk of the families are housed in separate dwellings, and less than 7 per cent share their dwelling with other families.

The general death rate in Niagara Falls is fairly uniform, averaging about 16 per 1,000, and compares favorably with other cities of this class. The comparison of the general death rate with the typhoid death rate is instructive. While the general death rate corresponds

closely with that of the registration cities of the United States, the typhoid death rate and the death rate for diarrhea and enteritis




have been out of all proportion, as shown by the following tables and charts:

| Year. | Deaths per 100,000 of population from diarrheal diseases. | |
|---|---|---|
| | Registration cities. | Niagara Falls. |
| 1900 | 144.7 | 113.1 |
| 1901 | 127.6 | 142.4 |
| 1902 | 119.9 | 141.1 |
| 1903 | 114.9 | 180.4 |
| 1904 | 125.8 | 179.7 |
| 1905 | 128.5 | 158.9 |
| 1906 | 135.6 | 161.7 |
| 1907 | 133.7 | 222.4 |
| 1908 | 128.0 | 143.7 |

Chart XVIII. Typhoid Fever. Deaths per 100,000, and General Death Rate per 1,000.
City of Niagara Falls compared with Registration Cities of the United States.

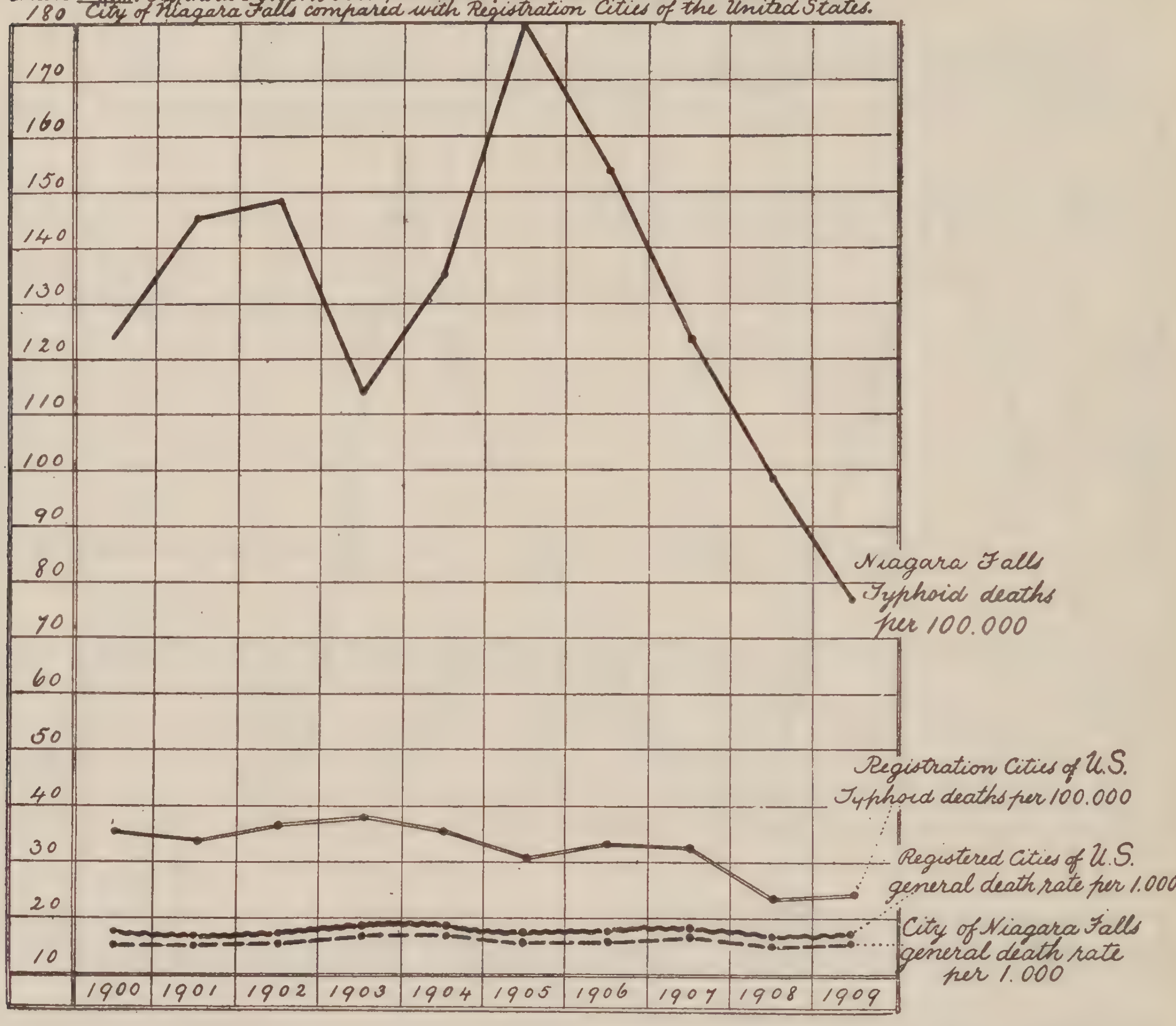
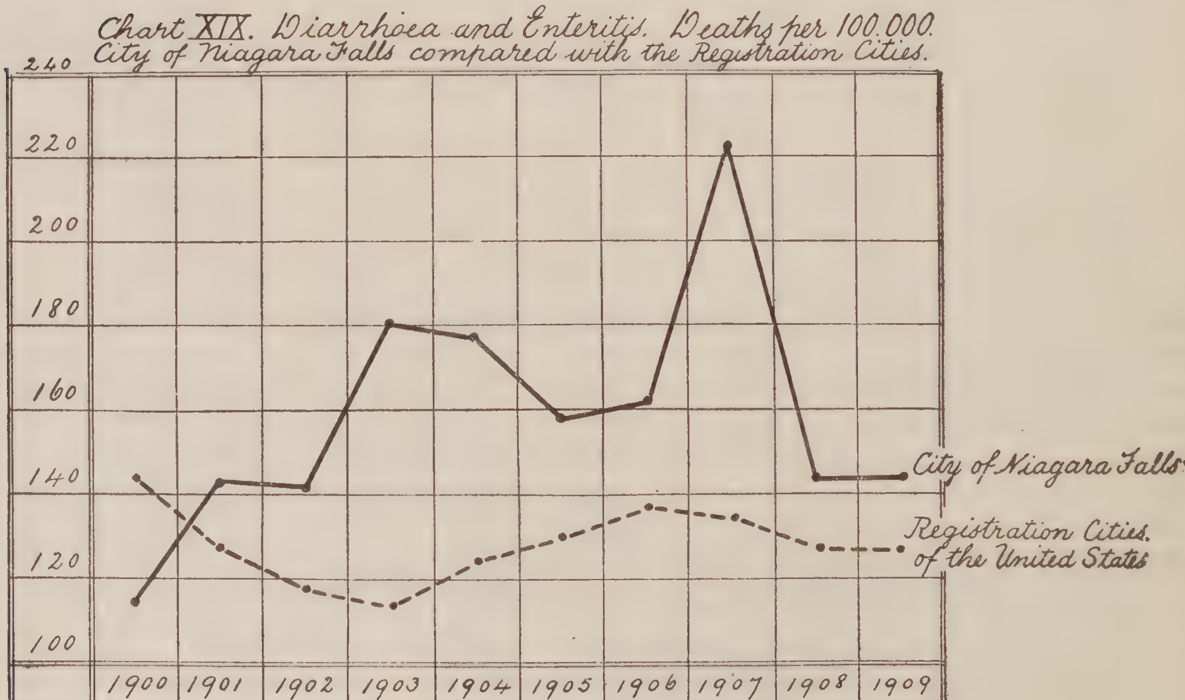



Chart XIX. Diarrhoea and Enteritis. Deaths per 100.000.
City of Niagara Falls compared with the Registration Cities.



The following table shows the excessive child mortality in Niagara Falls:

| Place. | Child mortality out of every 100 deaths at all ages in 1909. | |
|---|---|---|
| | Under 1 year. | Under 5 years. |
| Registration area | 19 | 27 |
| Registration cities | 20 | 28 |
| Niagara Falls | 27 | 34 |

Certain sociologic and economic conditions are generally conceded to be potent factors in child mortality. Chief among these are overcrowding or tenement-house congestion, high percentage of foreigners and illiteracy, high percentage of female factory or mill operatives, and, in general, a lack of prosperity.

HOUSING IN NIAGARA FALLS.

There is no overcrowding in Niagara Falls. The number of dwellings, according to the census of 1900, was 3,705, and the population at that time was 19,457, or an average of 5.2 persons per dwelling. This compares favorably with other cities in New York State, as shown by the following table:

| Cities. | Persons to each dwelling. | Cities. | Persons to each dwelling. |
|---|---|---|---|
| New York City | 13.7 | Utica | 6.2 |
| Yonkers | 9.0 | Syracuse | 5.7 |
| Cohoes | 8.0 | Binghamton | 5.6 |
| Troy | 7.8 | Rochester | 5.5 |
| Buffalo | 7.1 | Auburn | 5.3 |
| Schenectady | 7.0 | Niagara Falls | 5.2 |
| Albany | 6.9 | Elmira | 4.9 |

PERCENTAGE OF FOREIGN-BORN AND ILLITERATES.

The influence of the foreign-born element in a city upon the spread of disease and upon infant mortality is marked, and is probably due not only to their lower standard of living, but also to their inability to understand instructions calculated to prevent the spread of disease. In the same way the illiterate person of any nationality is unable to understand printed instructions, and his mental equipment is often such as to make it unlikely that he will carry out verbal ones.

Eighty-six per cent of Niagara Falls's foreign population is made up of English-Canadians, English, Irish, and Germans. The percentage of illiteracy is low.

FEMALE WORKERS IN FACTORIES OR MILLS.

In relation to child mortality it is interesting to note the ratio of women to total wage earners. Niagara Falls has a very low percentage of women workers. Its industries are such as require male labor. Cities whose chief industries are knitting, cotton, and silk mills, carpet, and shirt and collar factories, usually have a large number of women operatives, and child mortality is undoubtedly affected thereby.

| Cities. | Total wage earners. | Women over 16 years. | Percentage of women workers. |
|---|---|---|---|
| Amsterdam | 6,769 | 2,694 | 49.2 |
| Auburn | 6,530 | 1,709 | |
| Cohoes | 8,673 | 4,049 | |
| Elmira | 4,914 | 1,243 | |
| Newburgh | 3,920 | 1,223 | |
| Utica | 10,759 | 3,272 | |
| Yonkers | 8,615 | 2,782 | |
| Troy | 21,564 | 13,457 | |
| Niagara Falls | 3,518 | 557 | 15.8 |

In Niagara Falls the mothers, as a rule, are housewives, and do not work in factories or mills.

*Prosperity as indicated by the percentage of unencumbered homes and the average daily wage.*

| Cities. | Number of homes. | Number owned unencumbered. | Cities. | Number of homes. | Number owned unencumbered. |
|---|---|---|---|---|---|
| Auburn | 6,703 | 1,653 | Niagara Falls | 3,849 | 626 |
| Elmira | 8,084 | 1,961 | Amsterdam | 4,606 | 664 |
| Watertown | 5,029 | 1,167 | Cohoes | 4,971 | 695 |
| Jamestown | 5,595 | 1,081 | Mount Vernon | 4,330 | 506 |
| Binghamton | 9,318 | 1,717 | Newburgh | 5,836 | 919 |

Average percentage of unencumbered homes owned by occupants, 18.8.

In percentage of homes unencumbered and owned by occupants Niagara Falls is slightly below the average for the 10 cities above, but its percentage is considerably higher than that of Newburgh, Amsterdam, Cohoes, and Mount Vernon, as the following shows:

*Percentage unencumbered homes owned by occupants.*

| | | | |
|---|---|---|---|
| Niagara Falls | 16.2 | Cohoes | 13.9 |
| Newburgh | 15.7 | Mount Vernon | 11.6 |
| Amsterdam | 14.4 | | |

The following table shows wages paid in eight cities with approximately the same population in 1900 as Niagara Falls:

| Cities. | Population in 1900. | Number of wage earners. | Amount paid in wages. |
|---|---|---|---|
| Amsterdam | 20,999 | 6,769 | $2,680,359 |
| Cohoes | 23,910 | 8,673 | 3,140,668 |
| Jamestown | 22,892 | 4,685 | 1,800,192 |
| Kingston | 24,535 | 2,685 | 1,245,557 |
| Oswego | 22,199 | 3,845 | 1,543,905 |
| Poughkeepsie | 24,029 | 3,432 | 1,583,268 |
| Watertown | 21,696 | 3,760 | 1,821,477 |
| Newburgh | 24,943 | 3,926 | 1,665,177 |
| Total | ........ | 37,775 | 15,480,603 |

| | |
|---|---|
| Average yearly wage paid in above cities | $409 81 |
| Average yearly wage paid in Niagara Falls | 480.44 |
| Average yearly wage for State of New York | 481.54 |

From this it is seen that the average yearly wage for Niagara Falls is almost the same as that for the entire State, and considerably higher than the average for cities of the same size.

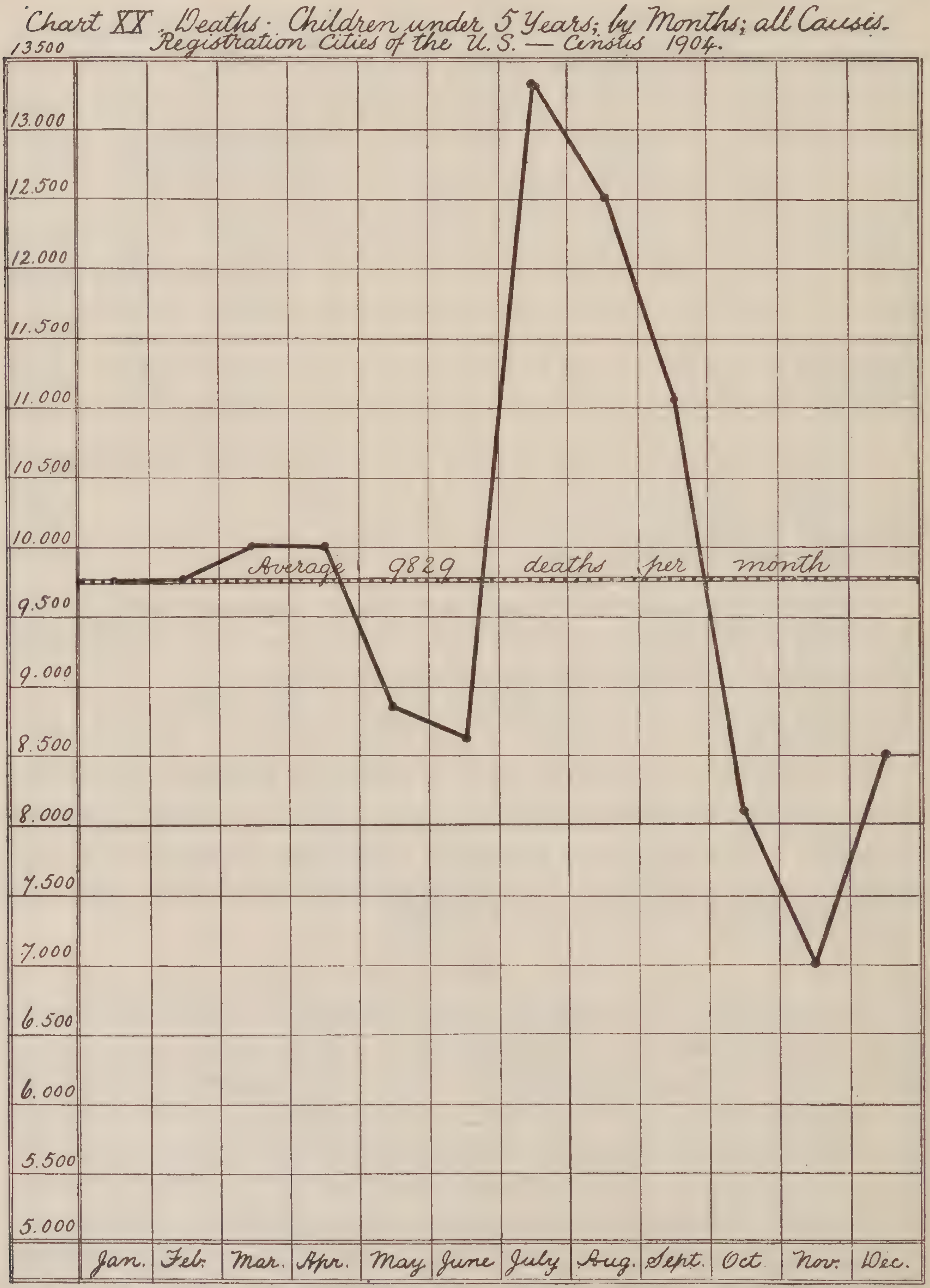
In view of these facts Niagara Falls must be considered a fairly prosperous city.

The accepted known factors in excessive child mortality are absent or not sufficiently pronounced in Niagara Falls to explain the high mortality. The social and economic conditions are such as should insure a low mortality in children, provided good milk and safe water were furnished to the inhabitants

MILK.

The regulations governing the care and handling of milk in Niagara Falls are sufficient, if enforced, to insure a good product if the milk reaches the city in good condition. The lack of control over the unit of milk production, the small farm, obtains here as in other sections. However, Niagara Falls is no worse in this respect than most other cities whose rate of child mortality is normal or below the average. In Niagara Falls, as in other cities, many children's deaths are probably due to milk, but the facts indicate that in Niagara Falls there is another factor besides milk operating constantly which keeps the mortality of children under 5 persistently high, and that this factor is probably the public water supply constantly polluted with the sewage of Buffalo and the Tonawandas.

Further, if the high mortality among children under 5 years was due to the average causes, the curve showing the deaths of children by months would correspond to that of the registration area. It will be

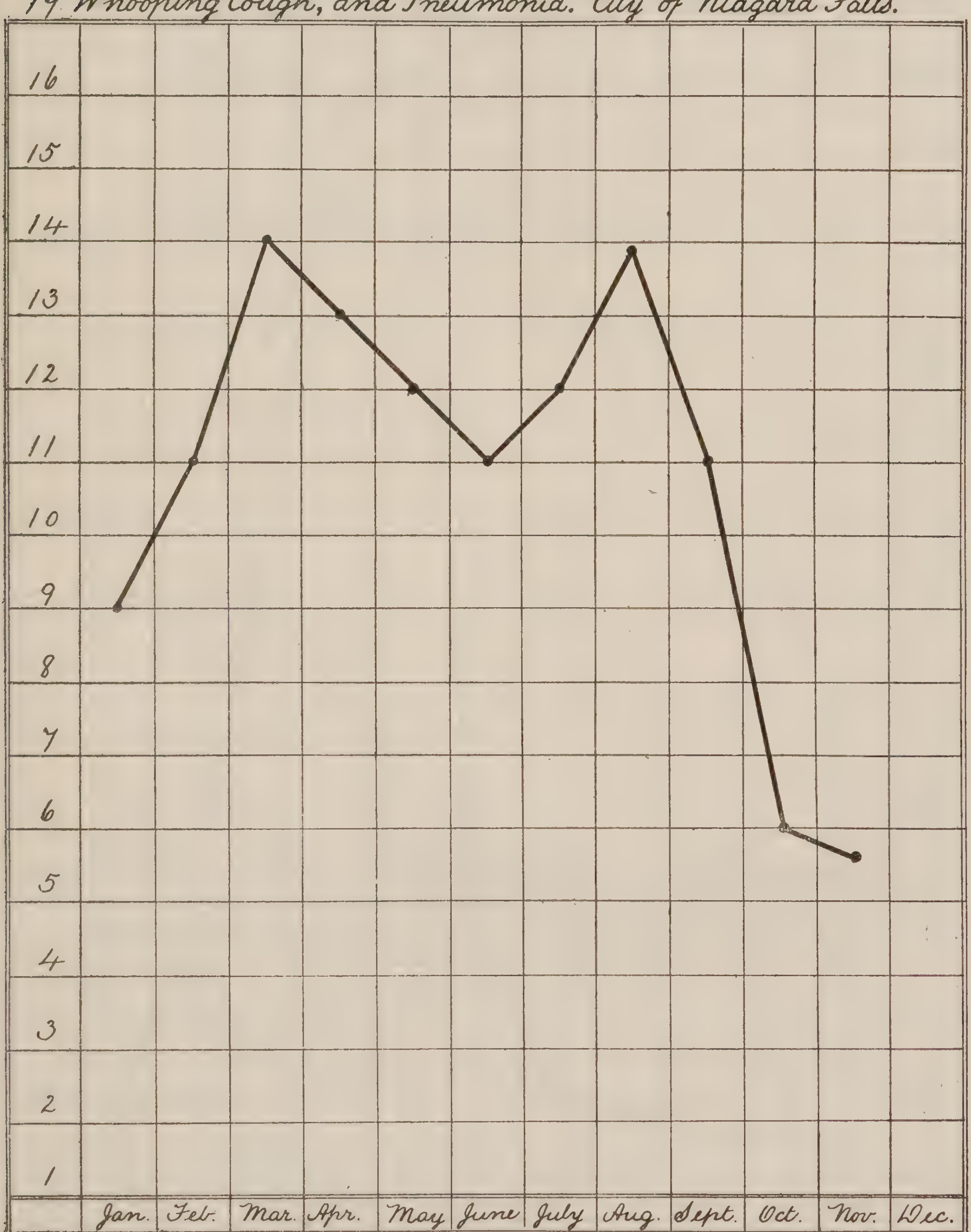



noted that this is not the case. The child mortality in Niagara Falls was altogether too high in February, March, and April; in fact, exclusive of measles, scarlet fever, whooping cough, diphtheria, menin-

gitis, and pneumonia, the deaths in February, March, and April were 38, against 39 for July, August, and September.

The deaths from enteritis are also too evenly distributed throughout the year. There is a rise in the curve showing seasonal preva-

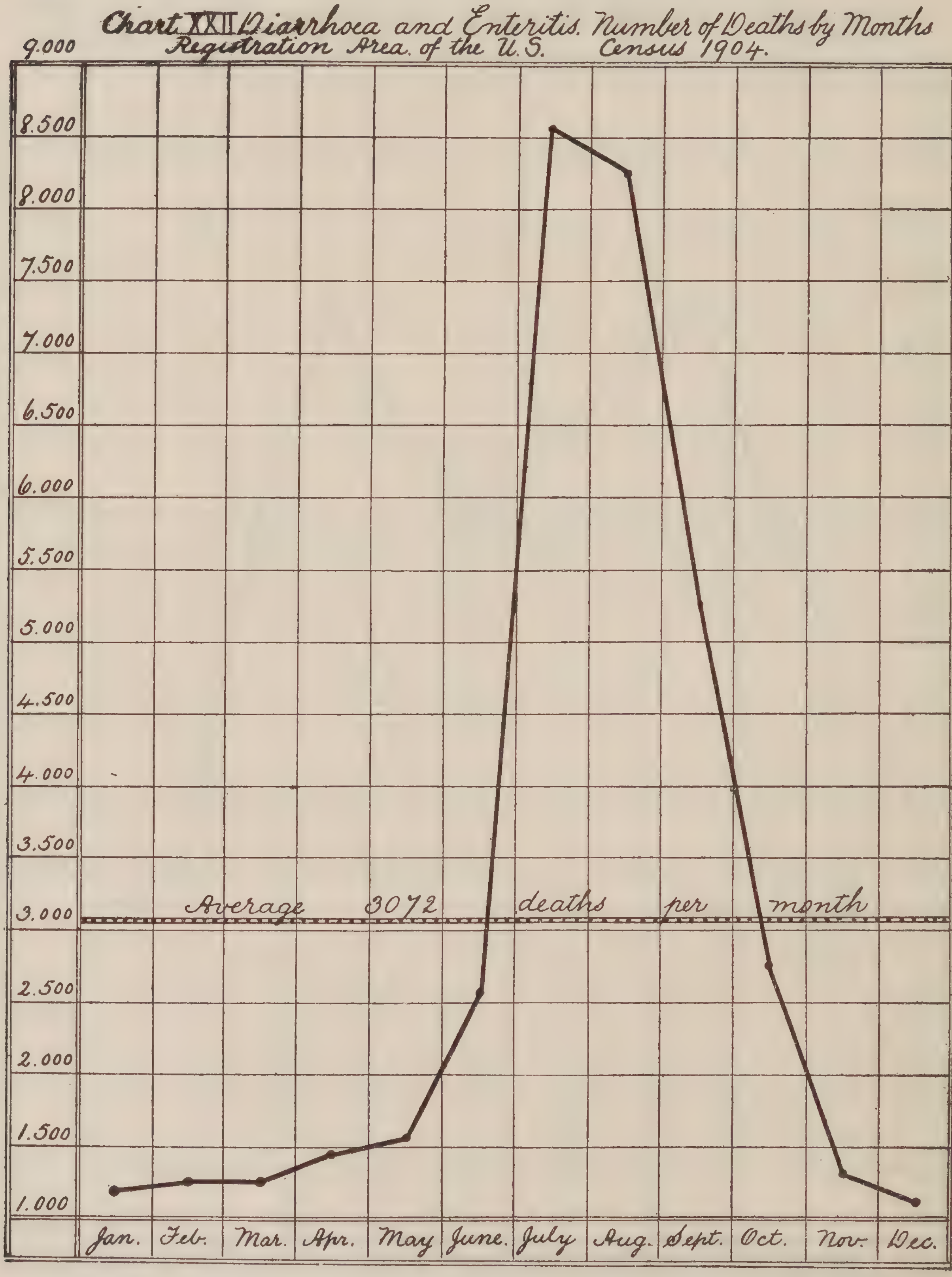
Chart XXI. Deaths; Children under 5 Years; by Months, 1910, exclusive of Measles, Scarlet Fever, Diphtheria, Meningitis, Whooping Cough, and Pneumonia. City of Niagara Falls.




lence by months for the months of July, August, and September, as might be expected, but there are too many deaths from enteritis in Niagara Falls in January, February, March, and April.

CONCLUSIONS.

1. Pollution from sources along the lake shore from the New York State boundary line to Canadaway Creek near Dunkirk is a negligible quantity. If the amount of pollution should increase because of




growth of population or from other causes, enforcement of State laws will efficiently dispose of the problem.

2. Canadaway Creek carries the sewage of Fredonia, which has a population of about 6,000, to the lake at a point $1\frac{1}{2}$ miles west of

Dunkirk. There is no question that Dunkirk's water supply is at times polluted from this source, the danger from such pollution being proportionate to and dependent upon the amount of typhoid organisms in Fredonia's sewage.

3. Dunkirk's water supply is also menaced, and under certain storm conditions is probably polluted from its own sewage. Typhoid fever in Dunkirk has had a high average rate for 10 years. It has been low for 1908 and 1909, but the number of cases increased again during 1910. The Dunkirk intake crib is 1,200 feet from shore and is probably not affected by that city's sewage, except under storm conditions.

Chart XXIII Diarrhoea and Enteritis. Deaths per 100.000 by Months. City of Niagara Falls. 1910.


4. Upon that portion of the shore of Lake Erie from Dunkirk to the boundary line of the city of Buffalo are situated several growing towns, such as Silver Creek, Hamburg, and the industrial towns of Lackawanna and West Seneca. The amount of pollution from these towns is considerable and increasing steadily. The State of New York has ample law to control this pollution, and has already taken steps to do so in Hamburg, Silver Creek, and West Seneca. Smoke Creek in the past was capable of polluting the old Buffalo intake. Part of the water from this creek, after passing through Buffalo Harbor, could and did pass westward of the Bird Island Pier, instead of entering Black Rock Harbor. Smoke Creek, however, should not

affect the water entering the new intake near Horseshoe Reef in the Emerald Channel, except under certain weather conditions.

5. The Buffalo River was a source of pollution to the old intake in the same manner and under the same weather conditions as Smoke Creek or any other polluted water passing through Buffalo Harbor. A portion of this polluted water always passed to the westward of the Bird Island Pier. The width of the zone of polluted water, measured from the Bird Island Pier and toward the intake, was variously estimated at from 200 to 300 feet, but it is ridiculous to expect that this width was never exceeded, and doubtless the zone of polluted water became at times more than 700 feet wide and extended to and beyond the intake. The new intake should be safe from this source of pollution except under certain storm conditions.

6. Buffalo is still using the old intake. Careful bacteriological examination of the water supply is made almost daily and warning is given to boil the water when the evidence of gross contamination is found.

There is no reason to believe that milk is responsible in Buffalo for more than an average amount of typhoid. The bacteriologist keeps a close watch upon milk and, cooperating with the bureau of food and drugs, has succeeded in establishing a higher standard for milk. Buffalo has the same milk problem as other cities and has advanced as far toward its solution as the average large city.

There is too much typhoid fever in Buffalo in spite of the excellent work done by the Buffalo department of health. Under existing conditions it must be inferred that a considerable portion of Buffalo's typhoid fever, especially in winter and spring, is due to a polluted water supply.

The quality of the water supply from the new intake is problematical. It will be in operation within a few months and its quality may then be determined with certainty. Some analyses have been made of water from near the new intake and these showed a good, safe water, but these analyses were few and were made under favorable conditions. Until daily examinations are made covering the entire year, during all sorts of weather conditions, judgment must be reserved as to whether a safe water supply can be obtained through the new intake without filtration or other treatment for every day in the year.

7. In regard to sewage disposal, Buffalo has done nothing beyond conveying its sewage to the Buffalo and Niagara Rivers. It amounts to about 160,000,000 gallons daily. Proper sewage disposal requires two things—it must not create a nuisance and it must not be a menace to health.

It is conceded that a stream flow of $3\frac{1}{2}$ to 7 cubic feet per second for each 1,000 of population will care for sewage so that no nuisance is created. According to this calculation, Buffalo would require for dis-

posal of its sewage, from the standpoint of nuisance, a stream flow of about 1,500 to 3,000 cubic feet per second. The Niagara River has a flow of about 220,000 cubic feet per second.

From the standpoint of menace to health, Buffalo's sewage disposal is another question. While the dilution is great, it is not as great as it appears at first glance because of the fact that the polluted current hugs the shore and complete dilution with the entire mass of water does not take place. Owing to the velocity of the stream, sedimentation is scarcely possible, and this velocity is another dangerous factor in carrying contamination quickly from Buffalo to the water fronts of other cities lower down the river.

The sewage of Buffalo is unquestionably a great menace to the inhabitants of the Tonawandas, Niagara Falls, and Lockport, just as the sewage of the Tonawandas is a menace in a lesser degree to the people of Niagara Falls, so long as these communities drink unfiltered or untreated water from the Niagara River. The position of the intake well out in the channel may protect from the shore pollution during good weather conditions, but its safety because of this is not assured. One thing is certain—the Niagara River can not be used as a sewer and at the same time be expected to furnish safe drinking water at all times without filtration or treatment of the water.

8. The Tonawandas, and now Lockport also, are exposed to pollution of their water supplies by Buffalo sewage. The pollution is intermittent because of the position of the intakes. The high typhoid rate in Lockport and the Tonawandas is probably due to this intermittent contamination of the water supply, other sanitary conditions in these cities being above the average.

9. Niagara Falls' water supply is polluted constantly by sewage from Buffalo and the Tonawandas and the death rate for typhoid fever has been constantly high for years and distributed throughout the entire year, indicating some constant source of infection. This source undoubtedly has been the Niagara River, used as a water supply. A small part of the total supply was filtered, but the filters were inadequate and worked beyond their capacity.

10. Even if the entire sewage of Buffalo was diverted from the Niagara River, there is a question whether this stream could furnish a raw—unfiltered or untreated—water safe to drink 365 days in the year. One tributary stream alone, the Buffalo River, empties into the Niagara in time of flood as much as 20,000 cubic feet per second—the drainage of a very large and populous area.

The question of practicability of stopping pollution of the Niagara River to the point of making the water safe for drinking purposes in its raw state requires very serious and close study. Certainly there are obstacles in the way which are very great from an engineering and economic standpoint. In view of these facts, it is the plain duty of municipalities now drinking Niagara River water without adequate

filtration to take steps toward making such water safe while awaiting the solution of the larger problem of sewage pollution of the stream.

11. These municipalities have all failed in their duty to provide safe water for their citizens. The Tonawandas had a sense of false security by reason of the position of the intakes. The municipal officials of Niagara Falls could have had no such delusion. They were informed by their own health officers, and must have known for years, that they were drinking dilute sewage and that the typhoid rate was continuously higher than any other American city, yet it was not until 1908 that steps were taken to filter the water, and the plant is not yet in operation. Niagara Falls' dereliction of duty was more culpable for another reason—during summer and autumn months thousands of persons visit the city from every State in the Union and from foreign countries as well.

12. The dangerous quality of water supplies taken from the Niagara River is a menace to the employees engaged in interstate traffic and to the thousands of tourists and visitors to Buffalo and Niagara Falls. There is a menace to other States by reason of possible infection caused by common carriers taking water or infected food supplies from these cities and from the return to their homes in other States of visitors and tourists. This latter is especially true of the thousands of people who visit Niagara Falls daily during July, August, and September.

Further inspection in the future will show what may be expected of the proposed new water supply for Buffalo and the new filtration plant for Niagara Falls.

13. There is reason to believe that the polluted public water supply of Niagara Falls may be a factor in the persistently high death rate from diarrheal diseases and for the excessive mortality among children under 5 years of age.

14. Experience teaches that the question of pollution of interstate waters can not be left to municipalities. Municipalities have no jurisdiction outside their corporate limits, nor do they seem to care if their sewage pollutes the water supply of another municipality.

There is a provision in the New York State law which provides for the prevention of the pollution of a public water supply by the sewage of another municipality, but the complaining municipality may only take action provided it has disposed of its own sewage without contaminating any river, stream, lake, or other body of water. As practically all municipalities are offenders in this regard, the law seems to be a dead letter.

15. The State board of health is doing everything possible within its power, but the State health laws are deficient in two important particulars:

First. They do not give the State board of health authority to stop or control pollution from sewers which existed prior to 1903.

Second. They do not give the power to the State to regulate public water supplies except when requested to make rules by the municipality; at least this seems to be the way the law is interpreted.

16. Prevention or control of pollution of interstate and international waters should be a function of the Federal Government. The problem can not be handled by States, as uniformity of law and unanimity of opinion is difficult to obtain and almost too much to expect.

There is no question of the duty of States to care for their own interests. There is, however, grave doubt of their ability or inclination to protect the interests of adjoining States, especially when such protection involves self-sacrifice in the interest of the common good.

Sooner or later the international phase of the question will become prominent, and the Dominion of Canada will expect to deal direct with the Federal Government and treat the entire question, rather than to take it up piecemeal with States whose authority is limited to certain sections of the problem.

## THE PENNSYLVANIA SHORE OF LAKE ERIE.

There is but one large community upon the Pennsylvania shore of Lake Erie, and sewage pollution of Lake Erie other than that furnished by the city of Erie, Pa., is a negligible quantity. There is a strong likelihood of a new city springing up east of Erie in the vicinity of Fourmile Creek. This new city is already planned by the Erie Improvement Association and the General Electric Co. Inasmuch as plans for a sewerage system are included, and that it is expected that the new city will have within a few years a population of 25,000, the project will be discussed after consideration of the city of Erie.

### ERIE, PA.

The city of Erie, Pa., covers an area of over 8 square miles and has a population, according to the United States census of 1910, of 66,525.

It is a city of considerable industrial and commercial importance and has enormous future possibilities. It is the only lake port in Pennsylvania, and has some of the largest boiler and engine works in the world. Free sites are offered with other inducements to large industries, and a great future development along industrial lines in Erie is to be expected. Because of its position, coal and iron deliveries are cheap in Erie. There is a large plant of the General Electric Power Co., which furnishes power for operating manufacturing plants.

Erie's manufactures are diversified—boilers, engines, electrical supplies and apparatus, and other industries involving the use of steel, brass, aluminum, and nickel are easily first, but in addition

paper, chemical, silk, and leather manufactures have a prominent place.

Erie has excellent railroad transportation facilities furnished by the Lake Shore, the "Nickel Plate," the Pennsylvania, and the Bessemer & Lake Erie Railroads.

Erie is situated upon the southern shore of Lake Erie, or, to be exact, upon what is known as Presque Isle Bay. Presque Isle Bay is completely landlocked except at the eastern end, where a 300-foot channel connects with Lake Erie. The bay is about 4 miles long and 1½ miles broad. It has an average depth of 15 feet, and a portion of the bay is 22 feet deep. Erie has a public dock constructed by the State of Pennsylvania, which is 557 feet long and 100 feet wide, a depth of 22 feet being maintained where necessary in the harbor by dredging. Erie Harbor or Presque Isle Bay is the only large natural harbor on the lake between Buffalo and Sandusky.

The Cleveland & Buffalo Transit Co. and the Anchor Line give steamer communication with Cleveland, Buffalo, Toledo, Detroit, Chicago, and upper lake ports. In addition to these passenger lines, an enormous freight traffic is carried on in the port of Erie. The following data shows the importance of Erie's lake traffic:

*Arrivals and departures of vessels at the port of Erie, Pa., for the year ending Dec. 31, 1910.*

| Vessels. | Arrivals from— | | | | Departures to— | | | |
|---|---|---|---|---|---|---|---|---|
| | Home ports. | | Foreign ports. | | Home ports. | | Foreign ports. | |
| | *No.* | *Tons.* | *No.* | *Tons.* | *No.* | *Tons.* | *No.* | *Tons.* |
| Steam | 887 | 1,779,696 | 193 | 78,499 | 925 | 1,780,350 | 164 | 70,512 |
| Sail | 30 | 33,397 | 20 | 8,380 | 44 | 73,418 | 18 | 5,223 |
| Barges | 23 | 67,614 | 11 | 4,574 | 5 | 5,127 | 10 | 3,291 |
| Total | 940 | 1,880,707 | 224 | 91,453 | 974 | 1,858,895 | 192 | 79,026 |

| | |
|---|---|
| Value of imports: | |
| By water | $210,946 |
| By rail | 108,023 |
| Value of exports by water | 234,697 |

Enrolled tonnage of port: Gross, 85,266; net, 60,047; vessels, 81; greatest draft of vessels, 21 feet.

*Receipts and shipments by water.*

| Articles. | Quantities. | Articles. | Quantities. |
|---|---|---|---|
| RECEIPTS. | | SHIPMENTS. | |
| Merchandise........tons.. | 73,689 | Merchandise........tons.. | 176,284 |
| Corn........bushels.. | 50,000 | Anthracite coal........do.... | 438,628 |
| Wheat........do.... | 578,730 | Bituminous coal........do.... | 421,931 |
| Flour........barrels.. | 1,215,895 | Railroad iron........do.... | 386 |
| Other mill products........tons.. | 81,925 | Pig iron........do.... | 553 |
| Lumber........feet.. | 10,798,020 | | |
| Cedar posts........pieces.. | 1,600 | | |
| Lath........bundles.. | 6,496 | | |
| Iron ore........tons.. | 942,592 | | |
| Copper........do.... | 9,638 | | |
| Sand and gravel........yards.. | 201,600 | | |
| Fish........tons.. | 5,930 | | |
| Pulpwood........cords.. | 40,249 | | |

These freight steamers often carry passengers in addition to their crews, and there is very direct connection between Erie and other lake cities which also have high typhoid rates. Over 2,300 vessels entered or departed from the port of Erie during 1910. The total tonnage of these vessels was greater than the total tonnage of vessels entering and leaving the port of Philadelphia, and amounted to nearly 4,000,000 tons.

In developing its industries Erie has taken full advantage of its fine harbor facilities and low lake freight rates, which are only one-third as high as railroad rates to the West and the Northwest.

## SEWERAGE SYSTEM.

The harbor inlet is confined between two piers. The south pier at its harbor end is joined at right angles by the south breakwater, which connects it with a projecting point of the mainland in front of the site of the Pennsylvania State Soldiers and Sailors' Home. The northern pier is situated 340 feet north of and parallel to the south pier. From the north pier Presque Isle extends in the form of a crescent to join the mainland about 4½ miles west of the harbor entrance, thus almost entirely inclosing Presque Isle Bay or Erie Harbor.

The city of Erie borders upon the bay or harbor for about 2 miles in a westerly direction from the inlet and upon the open lake for a distance of about 1 mile east of the harbor entrance and toward Four-mile Creek.

Along the shore of both bay and lake within the vicinity of Erie extends a bluff about 50 feet high. From this bluff the general level of the city rises gradually, till at the city line on the south the elevation is approximately 150 feet above the lake. The land continues to rise to the south, and within 3 miles of the city line reaches an elevation in Mill Creek Township of 550 feet.

The general land surface is a sloping plain from south to north, terminating in the above-mentioned bluff at the lake margin. From east to west the general level is only broken by gullies for the passage of streams to the lake. Five of these streams are within the limits of the city.

Cascade Creek is the most westerly of these streams and discharges into the bay. Little Cascade Creek rises in the city limits and discharges into the bay at the foot of Cherry Street. Mill Creek, the most important as a sewage carrier, rises in Green Township, about 10 miles southeast of Erie, and flows north through the city to the harbor, discharging by two mouths between the ore dock and the south breakwater, west of the point of land upon which is built the soldiers and sailors' home.

Garrison Run rises near the city limits, flows northwest through the city, and empties into the lake to the east of the projecting point of the soldiers and sailors' home. Lighthouse Run is the most easterly of the five streams and empties into the lake near the old Erie Lighthouse.

The sewers of Erie were built originally on the combined plan. Recent extensions have been largely of the separate type, the pipes ranging from 9 to 12 inches in diameter. About all of the city is sewered, and approximately 95 per cent of buildings on streets where sewers are laid have sewer connections.

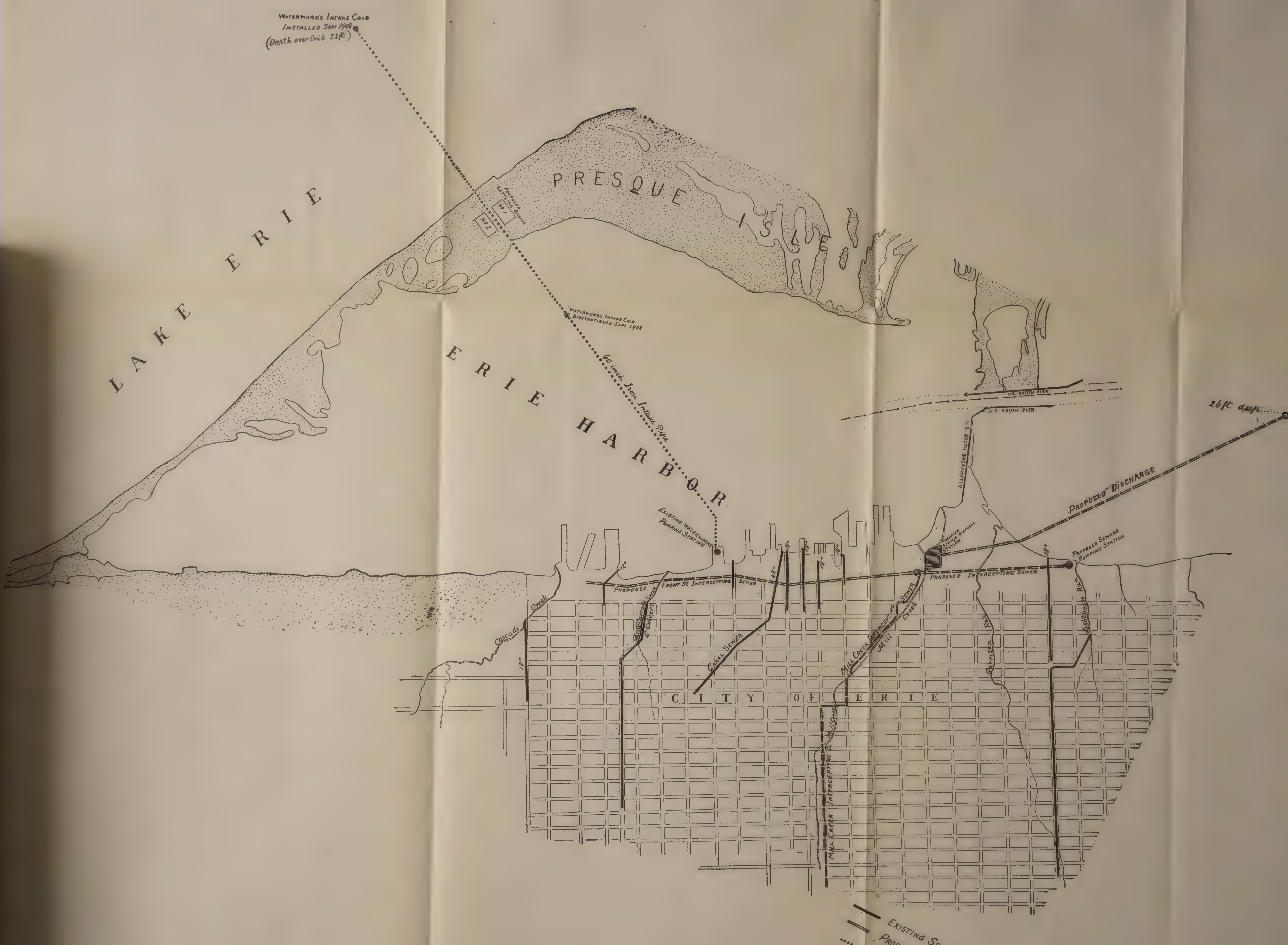
There are 11 sewer outlets into the harbor and 3 into Lake Erie east of the harbor, making a total of 14 city sewer outlets, counting Cascade Creek, Little Cascade Run, Mill Creek, Garrison Run, and Lighthouse Run each as a sewer outlet.

The system comprises a total of 79.86 miles, there being 68.94 miles of sewers discharging into the harbor and the remainder discharging into the lake. The following table shows these outlets and the length of tributary sewers, beginning at the west end of the city and named in order easterly:

| | Miles. | | Miles. |
|---|---|---|---|
| 1. Cascade Creek | 2.10 | 8. French Street | 0.74 |
| 2. Plum Street | .16 | 9. Between Holland and French | .20 |
| 3. Little Cascade Run | 14.40 | 10. Holland Street | .61 |
| 4. Myrtle Street | .15 | 11. Mill Creek | 42.60 |
| 5. Canal Street | 7.40 | 12. Wayne Street | 3.70 |
| 6. Peach Street | .37 | 13. East Avenue | .72 |
| 7. State Street | .21 | 14. Lighthouse Run | 6.50 |

Number 12 outlet is otherwise known as Garrison Run; it and the last two discharge into the lake, the other 11 emptying into the bay.

*Cascade Creek district.*—The Cascade Creek sewer outlet is an 18-inch pipe emptying into the creek at Cranberry and Fourth Streets, this being the westerly city line. The system comprises




MAP 8.—City of Erie, Pa., showing Erie Harbor (Presque Isle Bay) waterworks system, present sewer system, proposed intercepting sewers, and sewage disposal plant.

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2,100 feet of 18-inch pipe, 400 feet of 15-inch pipe, and the balance of the 2.1 miles have diameters ranging from 6 to 12 inches. They have been constructed since the law of 1905, without application to or approval by State officials. About 1 mile of the sewers is in the township.

Down this creek valley extend railroad tracks to three large railroad docks. The creek empties at the westerly dock. This structure is earth filled and extends out into the harbor 1,200 feet. It forms the bulkhead tending to hasten subsidence of suspended matters brought into the harbor by the creek. The prevailing westerly winds have full sweep here, and the wave action stirs up the deposits. There is always some creek flow, which during showers is accelerated to torrents which rush down the steep gorge, scouring out the sediment at the mouth and along the dock and carrying it beyond the end of the dock into the harbor.

A tributary of Cascade Creek has its source on a farm at the county almshouse from three springs, one of which furnishes water to the institution. The sewage during the winter season is discharged through a 12-inch pipe into the creek. In the summer time, the discharge is into a concrete tank about 25 feet in diameter and 6 feet deep, from which the liquid is siphoned out onto irrigation fields or filter ditches in gravel or sandy soil, into which the sewage disappears.

*Plum Street district.*—The Plum Street outlet is 12 inches in diameter. The 12-inch pipe is said to empty into an old drain under Front Street to the harbor just east of the third railroad dock.

*Little Cascade Run district.*—Little Cascade Run discharges into the harbor at the foot of Cherry Street. It is an open course from Third Street, except where it crosses under Second and Front Streets. Myrtle Street district (outlet No. 4) is at the foot of Myrtle Street and one block east of Chestnut Street.

*Canal Sewer district.*—The canal basin is at the foot of State Street on either side. It was built by the Commonwealth from proceeds of the sale of water lots directed by the assembly to be devoted to harbor improvements. The State canal from Erie over the summit to the Shenango and Beaver Rivers was a separate undertaking, so it is reported, and when finally abandoned was owned by the Pittsburg & Erie Railroad, which corporation conveyed the land to the abutting property owners. The canal sewer is a 4-foot brick structure, built in the former canal bed from Front Street to Ninth Street, a distance of 4,200 feet. It serves a well-built-up residential district, in which the sewer system all told comprises 7.4 miles, of which nearly 6 miles are pipes 15 inches or less in diameter.

The 4-foot outlet terminates in an unfilled portion of the canal bed in Front Street. There is an open ditch through the bed and

two 24-inch pipes under the filled part of Front Street, and thence an open ditch northerly to the canal basin, or that portion west of State Street. When the two 24-inch pipes are insufficient in capacity to deliver the flow from the 48-inch canal sewer, a pool of sewage forms in the hollow and becomes a great nuisance. However, ordinarily the sewage odors from the open ditch are offensive and have been the subject of much complaint. The western canal basin is about 750 feet long by 275 feet wide, and the eastern one is slightly larger. They are both surrounded by docks, except at the entrances. The modern steamboat landing has been erected northward from the canal basin to the harbor line in the extension of State Street. The waters of the west basin are especially filthy.

*Canal Basin sewer district.*—Outlet No. 6 is an 18-inch pipe into the west basin at the foot of Peach Street.

Outlets Nos. 7, 8, 9, and 10 are all into the east basin at the foot of State, French (between Holland and French), and Holland Streets, respectively; comprising all told 1.76 miles of sewers.

*Mill Creek district.*—Mill Creek discharges on the shores at the extreme eastern end of the harbor in a cove formed on the west by railroad docks and on the east by the grounds of the soldiers and sailors' home.

At its mouth there is an accumulation of earth deposit and sewage sludge brought down from the city and the outside country. The shores here were formerly sandy, then became miry, and the water in the cove became shallower. More complaint has been occasioned by the foul condition in this cove than by any other existing nuisance along the entire harbor front.

Second Street is at the head of the bluff. From here southerly up through the city the creek channel has an average depth of 17 feet below the streets, under which it passes through culverts and bridges, of which there are 20 in highways and 2 at railroads.

The channel is generally in shale rock, and has an average width of about 30 feet. In some places the sides are walled up, but between Ninth and Tenth Streets buildings are erected over it, and on its banks all through the city there are numerous dwellings, business blocks, and manufactories.

Except as above mentioned, the channel is open and in daily use as a repository for garbage, dry waste, rubbish of all kinds, and domestic and factory sewage. Outside of the city limits the waters of the creek appear to be unpolluted and clear and such as customarily flow from wooded and agricultural drainage areas, but within the city limits the stream becomes an open sewer and is offensive. It appears that the city has been a defendant in numerous suits for damages to abutting property owners by reason of the pollution of

Mill Creek. There are 43 open public sewer outlets into it, besides several private sewers.

The larger sewers empty into the creek at Fourth, Fifth, Seventeenth, and above Twenty-sixth Streets; the others are mostly short lines with a few laterals. There is one sewer 71 by 35 inches in size and one 51 inches, one 48 inches, and two 36 inches in diameter. There are six 2-foot sewers and the remainder are mostly 15-inch pipes. The largest number of miles of tributary sewers to any one outlet is 8.3 miles; the next is 6.9 miles; there is one having 6 miles, one having 4 miles, and one having 2.46 miles of tributary sewers. There are two which have about 1½ miles of sewers and the balance of the outlets serve short lines only.

In 1903 the average daily flow of these open sewer outlets into Mill Creek was 9,148,000 gallons. For the most part, the sewers discharge into the creek 3 feet or more above the bed of the channel. Quite a number of them are 6 or more feet above the bed.

*Garrison Run district.*—Garrison Run enters the lake on or near land of the soldiers and sailors' home. The stream rises above the city at the summit of the hills, passes northerly into the city, thence through a built-up section and under the extensive grounds used by the railroads for freight yards, repair shops, etc., in the eastern part of the city, and thence in an open channel, except where the run is intercepted by highways, to the grounds of the said soldiers and sailors' home and the lake. The existing outlets into Garrison Run are six in number, and their total length is 0.9 mile. The first two outlets are 15 inches in diameter, at Sixth Street; the next is 12 inches, at Eighth Street; there is also a 15-inch pipe emptying into the run at Tenth Street and two 12-inch pipes at Eleventh Street.

*East Avenue district.*—About 1,000 feet east of Garrison Run, at the foot of East Avenue, there is an 18-inch sewer which empties into the lake and serves a small district in which there are 0.72 mile of sewers, of which 0.54 is 18-inch pipe and the remainder 9-inch.

*Lighthouse Run district.*—Lighthouse Run is practically obliterated by the substitution of a drain inclosed and covered over, except the last 2,000 feet, which is an open channel from Lake Road to Lake Erie. It empties into the latter at the foot of Pennsylvania Avenue near the lighthouse. There are no dwellings in the vicinity. The mouth of this run is about 2,000 feet east of the mouth of Garrison Run.

The inclosed portion begins with a 40-inch culvert, and reduces to a 36-inch and then to a 30-inch sewer. The latter extends southerly up East Avenue from McCarter Street and terminates in a 20-inch pipe near the city line. Into this drain there are numerous sewers connected, the entire system comprising 6.5 miles, of which 3.8 miles are 15 inches or less in diameter.

*Summary of sewers.*—Of the 80 miles of public sewers in the city, about 70 miles or seven-eighths discharge into the harbor. Upward of 12 miles of new sewers have been constructed without State approval, some of them being extensions of existing sewer outlets and others being tributary to new outlets thus established. It is reported, as hereinbefore stated, that the latest lateral additions are used as sanitary sewers only. If roof water has been admitted, it is said to have been under conditions which permit of its being run out from the sewers whenever necessary. The other sewers are combined.

The sewage from the soldiers and sailors' home is partly discharged into Garrison Run and partly into Mill Creek.

The sewage from the docks and ships and from manufacturing plants along the shore goes into the harbor. Numerous cottages and clubhouses and a small town called Fern Cliffe add to the pollution of the bay waters.

## PRIVIES.

It will be noted that Erie is a well-sewered city in so far as access to sewers is concerned. In spite of this there were formerly a great many insanitary privies. The local health officer has endeavored for years to eliminate the outdoor insanitary privy in Erie, and in 1908, 1909, and 1910 succeeded in abating over 1,600 of these nuisances. During the greatest activity of the health authorities in 1909 the local plumbers combined to increase the cost of plumbing installations to almost double the former rate. This, together with the poverty of some householders and the small value of some of the houses, is sufficient to make the work of eliminating the remaining privies necessarily slow. There remain about 1,400 of these insanitary privies. There is a regulation requiring that the vaults be cleaned before the contents reach within 2 feet of the top of the vault, but this is not always enforced, and many of these vaults are actually overflowing. Night soil is handled in as unsatisfactory a manner as garbage. The scavengers work on the fee system, and the vault contents are carted out in the country to be disposed of to farmers. There is too little municipal control either of the collection or the disposal.

## GARBAGE DISPOSAL.

The system, or rather lack of system, of garbage disposal in Erie is very unsatisfactory. The collection is in the hands of so-called licensed scavengers, and these collect fees from the householder for removing garbage and refuse. Garbage and refuse are allowed to accumulate, especially in the poorer districts, because of the fault of the system. The scavenger naturally prefers to work where he can find the cleanest garbage and the readiest pay. In the districts where he is needed most he is seen at rare intervals, and only after pressure from the local health officer has been applied.

For years Dr. Wright, the city health officer, has advocated municipal garbage collection and incineration. With the moral stimulus of the typhoid epidemic and the support of the State health authorities, the local health officer, February 21, 1911, succeeded in getting the councils to pass a resolution providing for an incinerator and municipal collection of garbage. In the past the garbage was either permitted to accumulate at the back door in filthy back yards or it was carted out in the country to be disposed of to farmers for swine food or as manure. A considerable portion was also dumped in vacant lots, alleys, and watercourses.

## MILK.

Erie's milk supply is drawn from the adjoining country, and every farm supplying milk to Erie is inspected and rated by the score-card system adopted by the United States Department of Agriculture. Erie is fortunate in having access to the unit of milk production (the farm) for purposes of inspection. This system was established in 1908, and some improvement followed in 1909, as shown by inspection records.

| Years. | Condition of dairy. | | | Total. |
|---|---|---|---|---|
| | Good. | Fair. | Poor or bad. | |
| 1908 | 3 | 94 | 342 | 439 |
| 1909 | 14 | 142 | 259 | 415 |

Twenty-five of the worst dairies went out of business, 48 improved from a bad or poor rating to fair, and there was an increase from 3 to 14 in good. There was still further improvement in 1910. Milk after reaching the city of Erie is handled under the strict regulations of the local board of health. Fifty per cent of all the milk delivered in Erie is distributed by the Erie County Milk Association. The other half of the milk supply is handled by about 65 individual vendors. Milk can only be sold in Erie by a licensed vendor, and this license is granted and held subject to the approval of the board of health. The vendor signs an agreement to conform to the strict rules of the board, and these rules provide for sterilization of containers, maintenance upon ice, and other necessary measures.

## WATERWORKS SYSTEM.

The waterworks system comprises an intake crib in the lake and two in the bay, a pumping station, a storage reservoir, and a distributing system.

The older of the two intakes in the bay is a 4-foot pipe, 975 feet long, terminating in a crib opposite the pumping station at the foot of Chestnut Street. It has been damaged and is not used, except

possibly in emergencies, because of sewage pollution of the waters there.

This old intake was constructed in 1868. The second bay intake was completed in 1896. It was a 60-inch steel pipe, 8,307 feet long, buried at least 3 feet deep in the bed of the bay and terminating at the outer end in an octagonal crib 40 feet in extreme width and 8 feet high, the top being 13 feet below the bay level. The location of this intake is about three-quarters of the distance across the harbor.

The present intake is an extension of the 60-inch steel pipe across Presque Isle out in the lake a distance of 1 mile from the north shore of Presque Isle. The right to extend the intake pipe under the bay, and thence across the land belonging to the United States on the peninsula to the shore of Lake Erie and as far as necessary out into said lake to secure pure water, together with the right to use of such land on the peninsula necessary to install settling basins and filter beds, was granted to the commissioners of waterworks by an act of Congress in 1893. The old intake on the 60-inch pipe in the bay is maintained for emergency uses.

The pumping station houses three steam engines. One raises water into the distributing pipe in the higher districts of the city, from which there is an overflow arrangement to the reservoir; the others raise the water into the lower district of the city and thence into the reservoir.

There are 125 miles of street mains, whose diameters vary from 4 to 30 inches.

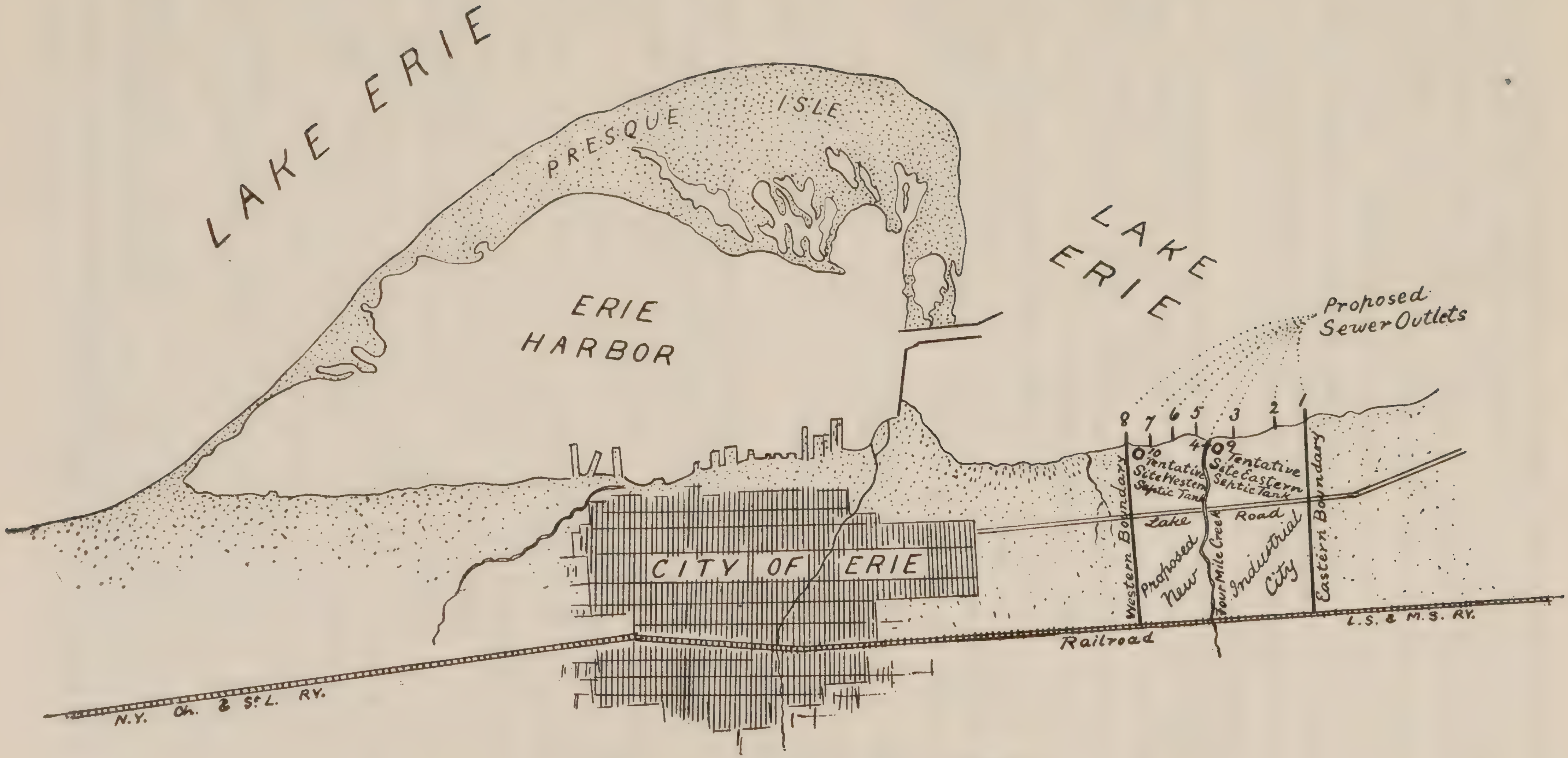
The storage reservoir on the hill, constructed in 1873, holds when full 32,950,000 gallons, the average depth of the water then being 26½ feet and the surface 237 feet above the harbor level. The structure is an earth embankment 545 feet long by 422 feet wide, interior dimensions, the bottom and sides are laid in brick cemented, and there is a center wall. The reservoir is distant back on the hillside about 2 miles from the pumping station.

The daily consumption for all purposes is reported to be a little less than 12,000,000 gallons. Practically everybody depends upon and uses the public supply, and wells are a negligible quantity.

### A NEW INDUSTRIAL CITY.

In 1908 a corporation known as the Erie Improvement Co. requested permission from the State board of health to construct and operate a sewer system in Mill Creek and Harbor Creek Townships and to discharge sewage untreated into Lake Erie. The following data relating to the proposed new city are taken from the report of the State commissioner of health, 1908.

It appears that the Erie Improvement Co. was chartered October 30, 1907, for the construction and maintenance of sewers, drains,




MAP 9.—Showing proposed new industrial city near Erie, Pa.

culverts, conduits, and pipes, with all the necessary inlets, outlets, and means of disposal for surface an undersurface and sewerage drainage, in the territory now within the bounds of Mill Creek and Harbor Creek Townships, in Erie County, Pa., including the construction, carry on and maintenance of such means and appliance as may tend to improve or advance the health, comfort, and convenience of the inhabitants and sanitary conditions within the boundaries of said townships, and for the purpose above set forth to enter upon and occupy any public highway with the consent of the local authorities.

The Pennsylvania General Electric Co. contemplates the construction of a manufacturing plant on a tract of several hundred acres of farm land lying about 1½ miles east of the eastern boundary of the city of Erie, for the manufacture and use of various kinds of electrical machinery, apparatus, etc.

In the development of this plant said company purposes to construct a system of sewers with an outlet northward to Lake Erie.

The Erie Improvement Co. contemplates the construction of other sewers which are designed to form a system a part of which shall be the sewers at the said General Electric Co.'s plant.

About 1,000 acres of farm lands have been purchased by a representative of the Pennsylvania General Electric Co., who now holds the title to the land upon which it is proposed by said company to erect its plant.

The population at present living on these lands is approximately 100 people. The northern boundary of the property extends to Lake Erie. The southern boundary is the Lake Shore & Michigan Southern Railroad, and also the Nickel Plate Road, so called. A small portion of the eastern part is in Harbor Creek Township and the remainder in Mill Creek Township. The ground at the lake terminates abruptly in a bluff from 30 to 50 feet above the lake level. Back from the bluff the ground ascends in a gentle slope southerly. In an easterly and westerly direction the surface is uniform except where it is cut by small ravines. A stream known as Fourmile Creek rises in Green Township about 7 miles to the south, drains a rural territory, passes through the eastern end of the property under discussion and enters the lake in Mill Creek Township, near Harbor Creek Township, 2 miles easterly from the Erie city line.

The territory is underlaid with shale rock. Near the railroads the rock is about 2 feet below the surface of the ground, and at the lake it is about 10 to 15 feet below.

Here, if expectations be realized, will spring into existence within five years a community of 10,000 people. Possibly within the next 25 years, should the business of the proposed plant develop, the population may reach 50,000 people.

The proposed domestic water system is planned for 20,000 employees and 25,000 town inhabitants besides. The estimated consumption is 2,600,000 gallons per day. It is reported that arrangements have been made with the water commissioners of Erie city to furnish drinking water to the settlement and for the plant. It appears that the system for fire protection is to be installed by the General Electric Co., the water for this purpose to be taken from the lake. There is to be an emergency connection with the Erie city water mains. Plans and an application for their approval have not been submitted to the commissioner of health for the above waterworks either by the city authorities or the private corporations.

The number of men to be employed at the works will for a considerable length of time be limited. Consequently the amount of sewage will be small. Such portions of the sewer system are to be built as may be deemed necessary from time to time by said companies as the business of each may justify.

Detail plans of sewers have not yet been prepared. The general plan submitted shows three shore sewer outlets east of the creek, one in the creek near its mouth, and four shore sewer outlets west of the creek.

### DIARRHEA, ENTERITIS, AND CHILD MORTALITY.

From consideration of the social, economic, and industrial conditions in Erie it is not to be expected that high death rates for diarrhea and enteritis or for child mortality would be found. As a matter of fact, Erie compares very favorably with other cities in the number of deaths from diarrhea and enteritis, as shown by the following table:

| Cities. | Average diarrhea and enteritis death rate per 100,000 of population for 5 years, 1904–1908. | Infant and child mortality out of every 100 deaths at all ages in 1909. | |
|---|---|---|---|
| | | Under 1 year. | Under 5 years. |
| Waterbury, Conn. | 216.8 | 30 | 39 |
| Manchester, N. H. | 195.8 | 31 | 42 |
| Holyoke, Mass. | 199.8 | 37 | 44 |
| Somerville, Mass. | 75.9 | 15 | 22 |
| Bayonne, N. J. | 224.9 | 31 | 44 |
| Hoboken, N. J. | 145.7 | 20 | 32 |
| Schenectady, N. Y. | 164.7 | 25 | 35 |
| Utica, N. Y. | 133.7 | 22 | 28 |
| Erie, Pa. | 116.6 | 24 | 34 |
| Harrisburg, Pa. | 65.2 | 17 | 24 |
| Wilkes-Barre, Pa. | [1] 147.0 | 21 | 32 |
| Johnstown, Pa. | 122.6 | 28 | 43 |
| State of Pennsylvania | [1] 149.9 | 23 | 33 |
| Cities in registration States | 140.2 | 20 | 29 |

[1] Three years, 1906–1908.

The table shows that Erie has a lower rate than any city in the list except Somerville, Mass., and Harrisburg, Pa., and is considerably lower than the average for the State of Pennsylvania as a whole, and of the average for cities in registration States.

The parallelism between high death rates from diarrhea and enteritis and child and infant mortality is shown clearly in the above table. The cities with low rates for diarrhea and enteritis, as Somerville, Mass., and Harrisburg, Pa., have also low percentage of deaths under 1 and 5 years.

Bayonne, N. J., Holyoke, Mass., Waterbury, Conn., and Manchester, N. H., have excessively high death rates for diarrhea and enteritis, and have a correspondingly high infant and child mortality.

Erie's percentage of deaths under 1 and under 5 years is slightly above the average for the State of Pennsylvania. In view of the absence of economic, social, or industrial conditions to warrant this increase, and considering the low death rates for diarrhea and enteritis, some other cause must be sought for explanation of this slight discrepancy.

The figures in the above table showing percentage of deaths under 1 and 5 years are for the year 1909. A consideration of the deaths in this class of cities for 1909 from measles, scarlet fever, diphtheria, and whooping cough, as shown in the following table, may offer the explanation sought:

| Cities. | Measles. | Scarlet fever. | Whooping cough. | Diphtheria. | Total. |
|---|---|---|---|---|---|
| Waterbury, Conn | 5 | 0 | 1 | 17 | 23 |
| Manchester, N. H | 15 | 0 | 20 | 35 | 70 |
| Holyoke, Mass | 4 | 2 | 6 | 11 | 23 |
| Somerville, Mass | 10 | 10 | 10 | 30 | 60 |
| Bayonne, N. J | 3 | 5 | 3 | 12 | 23 |
| Hoboken, N. J | 16 | 22 | 8 | 28 | 74 |
| Schenectady, N. Y | 2 | 20 | 6 | 8 | 36 |
| Utica, N. Y | 13 | 8 | 6 | 7 | 34 |
| Erie, Pa | 32 | 2 | 28 | 9 | 71 |
| Johnstown, Pa | 8 | 38 | 6 | 21 | 73 |
| Harrisburg, Pa | 5 | 2 | 4 | 27 | 38 |
| Wilkes-Barre, Pa | 12 | 9 | 6 | 21 | 48 |
| Total | 125 | 118 | 104 | 226 | 573 |

The above table shows clearly the cause of the increased child mortality in Erie in 1909. Of the 104 deaths from whooping cough in these 12 cities, 28, or nearly 27 per cent of the total, occurred in Erie. Of 125 deaths from measles in the same 12 cities, 32, or over 25 per cent, occurred in Erie.

The high death rate for the infectious diseases of children in Erie is shown even more graphically by a summary from the above table

comparing deaths in Erie with the average deaths in the 12 cities combined:

| | Measles. | Scarlet fever. | Whooping cough. | Diphtheria. | Total. | Diarrhea and enteritis. |
|---|---|---|---|---|---|---|
| Average number of deaths for 12 cities... | 10.4 | 9.8 | 8.6 | 18.8 | 47.9 | 102.8 |
| Number of deaths in Erie, Pa.......... | 32.0 | 2.0 | 28.0 | 9.0 | 71.0 | 88.0 |

WINTER CHOLERA.

About December 15, 1910, an outbreak of an explosive character of a disease which local practitioners called "winter cholera" occurred in Erie. Its spread was rapid and thousands were attacked within a few weeks. Estimates of the number of cases vary from 10,000 to 30,000, but no observer estimated less than 10,000 cases. The State board of health and the local health authorities made a canvas in an effort to estimate the number of cases, and their results suggested that one-third of the population suffered from the malady. The symptoms were often slight and transient, and the result never fatal, except, perhaps, in the old and feeble, hence it was difficult to obtain a correct estimate of the number of cases which occurred. The clynical picture as given by various physicians was remarkably uniform, and Dr. Wright, city health officer, gives the following description:

So-called winter cholera occurring in this city showed the following symptoms: A sudden onset with no general constitutional symptoms, the patient's illness being confined to griping abdominal pains covering a period ranging from one to five or six hours followed by profuse watery stools, lasting, in the ordinary instance, from one to two days. In cases where the disease did not terminate quickly a slight rise in temperature was noted, the curvature rarely ranging higher than 100°. The character of the stool, if the disease persisted longer than two days, was mucoidal, with the presence of more or less blood; in fact, a dysenteric type.

In cases occurring under my personal observation a considerable degree of flatulence was noted; the rise in temperature above noted occurred only in a very small percentage of these cases, and then only in the more aggravated type.

This outbreak of winter cholera took place during the second and third weeks of December, 1910. It antedated the explosive typhoid outbreak about two or three weeks. It seems probable that the so-called winter cholera is a disease caused by sewage-polluted water, and that it was caused in Erie by the same gross pollution of the water supply which was responsible for the typhoid outbreak occurring two to three weeks later; the difference in time between the outbreaks being due to the difference in the incubation period of the two diseases.

In all probability this disease is much more prevalent than the records would indicate. Because of its low mortality and transient character, it often escapes official record.

TYPHOID FEVER.

The table given below shows the persistently high typhoid death rate in Erie, Pa., compared with other cities of approximately the same size. One of these cities is in New Hampshire, one in Connecticut, two are in Massachusetts, two in New Jersey, and two in New York. Three other Pennsylvania cities fall within this category (55,000 to 75,000 population) and these three cities, like Erie, have a high typhoid death rate.

*Typhoid death rate per 100,000 in 12 American cities with populations of 55,000 to 75,000.*

| Cities. | Population. | Average typhoid death rate per 100,000 for 5 years, 1904–1908. |
|---|---|---|
| Waterbury, Conn. | 73,141 | 23.9 |
| Holyoke, Mass. | 57,730 | 8.2 |
| Somerville, Mass. | 75,964 | 14.7 |
| Manchester, N. H. | 70,063 | 19.4 |
| Hoboken, N. J. | 70,324 | 17.7 |
| Bayonne, N. J. | 55,545 | 13.9 |
| Schenectady, N. Y. | 72,826 | 14.7 |
| Utica, N. Y. | 74,419 | 19.6 |
| Erie, Pa. | 66,525 | 50.9 |
| Johnstown, Pa. | 55,482 | 60.2 |
| Harrisburg, Pa. | 64,186 | 59.3 |
| Wilkes-Barre, Pa. | 67,105 | 33.6 |

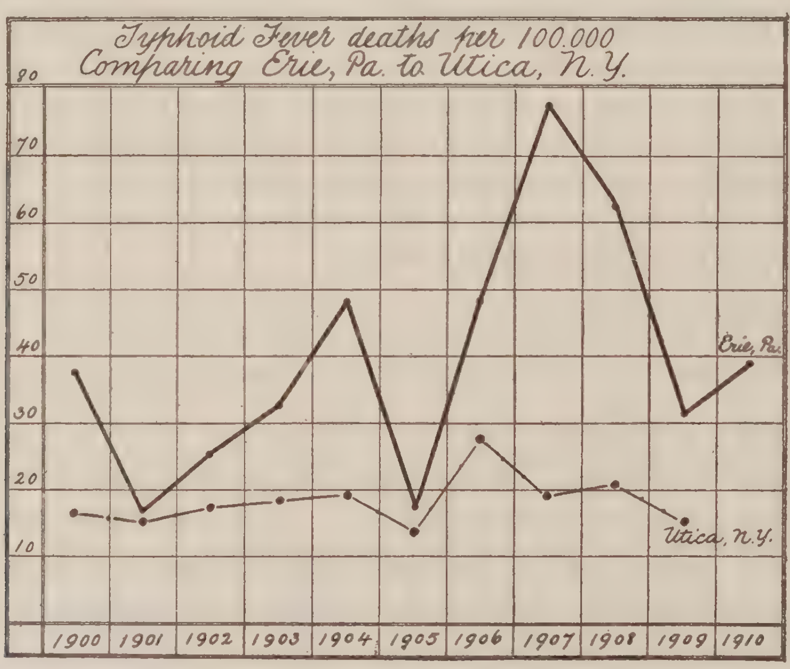



CHART XXIV.

The charts numbered XXIV, XXV, XXVI, and XXVII, show graphically the relative prevalence of typhoid fever in Erie, Pa., compared with a city of about the same population in each of the States of New York, New Jersey, New Hampshire, and Massachusetts.

The study of typhoid fever in Erie, Pa., since 1880 is inseparable from a study of the sources used for the public water supply, and naturally divides itself into five periods, as follows:

| Period. | Average typhoid death rate. | Period. | Average typhoid death rate. |
|---|---|---|---|
| 1880 to 1889 | 32 | 1902 to 1908 | 44.8 |
| 1890 to 1895 | 52 | 1909 to 1910 | 34 |
| 1896 to 1901 | 25.2 | | |

The first city supply was from springs and was carried into the town in wooden logs. In 1868 this system was abandoned and the water was taken from the harbor 975 feet from shore. This was not far enough from the water front of a growing town and after some years typhoid increased rapidly.

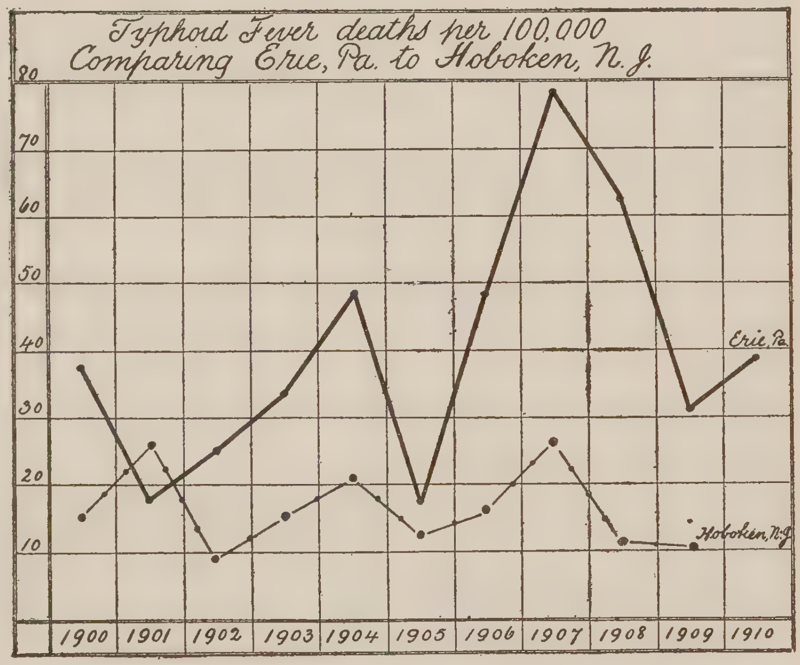



CHART XXV.

During the first period, 1880 to 1889, the constantly increasing volume of sewage gradually made unfit for use water taken at a point less than 1,000 feet from the sewer outfalls.

The second period, 1890 to 1895, covers the time during which patient citizens continued to use the water, in spite of the steadily increasing typhoid and general death rates.

The average for the period from 1890 to 1895 was 52 deaths per 100,000. The constantly increasing volume of sewage poured into the harbor made necessary some change in the water-supply system, and a new intake was constructed 8,000 feet from the sewer outlets, three-fourths of the distance across the harbor toward Presque Isle, in what is known as Big Bend. From the intake a 60-inch steel pipe conveyed the water to the pumping station; although the intake was extended 7,000 feet farther from the sewers, it was still, however, within the same polluted harbor.

The third period, 1896 to 1901, represents a period during the early part of which reduction of typhoid fever was effected by moving the intake farther from the sources of pollution. In other words, while

pollution of the intake still took place at times, it was less constant than at the old intakes 975 feet from the sewer outlets.

As might have been anticipated, in 1897 the typhoid death rate dropped to 26, and in 1898 to 16 per 100,000. The average for the five-year period immediately following the installation of the new intake was 25.2.

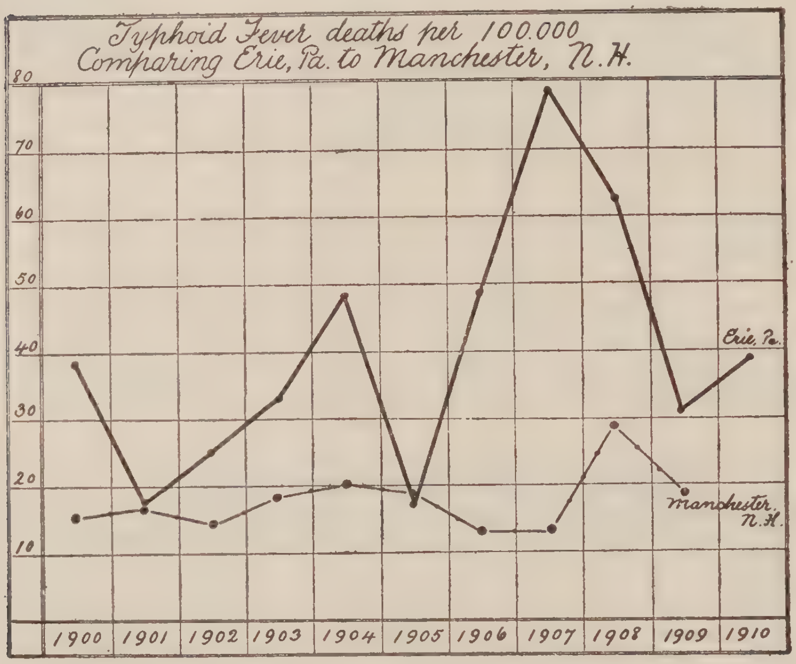


CHART XXVI.

The fourth period, 1902 to 1908, represents the growth of conditions approximating those of the second period; the amount of sewage pollution increased very rapidly and showed that the relief afforded by the new intake was but temporary.

Erie Harbor seems an ideal sedimentation basin. By natural agencies it was capable of purifying a large amount of organic filth or sewage, and it did purify large amounts for years. However, the natural powers of purification, especially sedimentation, were impaired and interfered with by the wave action due to winds and the movements of vessels. In certain seasons large creeks in flood not only carried large quantities of sewage to the bay, but carried it far out in the bay to the intake itself.

CHART XXVII.

In the earlier years it was not to be expected that filtration of the water supply would be resorted to by the water commission of Erie. Such an expectation would have presupposed an extraordinary knowledge of cause and effect in the transmission of typhoid fever which was not common knowledge at that time except among sanitarians. In 1902, however, the commis-

sioners of waterworks in their report practically admitted the sewage pollution of the water and said:

> This problem might be solved by the adoption of any of the following plans: (1) The construction of an intercepting sewer along the city front which would prevent any sewage from entering the bay; (2) the construction of a filtration plant; (3) the extension of the intake pipe into Lake Erie.

From 1902 to 1908 is a period during which it was evident that sewage pollution of the intake took place almost constantly. Some time seems to have been spent in an attempt by the water commissioners to have the councils construct an intercepting sewer to carry all the sewage to some point outside the harbor entrance. In 1903, however, the water commission evidently decided that the construction of the sewer was not contemplated by the city, and decided to extend the 60-inch steel pipe across Presque Isle and 5,000 feet out into the lake. This work was completed in 1908.

The fifth period covers the time since Lake Erie was substituted for the harbor as a source of public water supply. During this period the water commissioners, and probably most other officials in Erie, believed that uniformly pure water could be secured by going out into Lake Erie. They further believed, the intake being 4 or 5 miles from the harbor entrance, that the prevailing lake current would carry the sewage-polluted water from the harbor entrance eastward away from the intake.

Subsequent happenings in January and February, 1911, showed how fallacious was this belief and how insecure was the protection afforded by unstable lake currents. Placing an intake a few miles to the westward of a constant source of gross pollution and depending upon the supposed prevailing winds and currents to carry the sewage-laden water eastward is a blunder of which not Erie alone has been guilty, but the same practice has been resorted to and the same blunder has been committed by nearly every city on Lake Erie.

Since September, 1908, when the new intake was completed, Erie's water supply may be said to have been subject to occasional pollution only. In 1909 it evidently escaped gross pollution.

In 1910 there were only 5 cases in January and 17 in February, but there was a rise to 48 in March. The average for March for 10 years was 19.5 cases, and a rise to 48 was suggestive of the possibility of sewage pollution of the water supply.

Chart XXVIII shows the continued excessive typhoid rates in Erie since 1880. In 1883 and 1884 the rate was below 20—a moderate rate. In 1887 it was again below 20, but it never was below 33—an excessively high rate—from 1887 until 1897, when it dropped to 26, after moving the intake 7,000 feet farther out in the bay. The next year, 1898, it dropped still lower—to 16. In 1901 and 1905 it again reached a low figure, and in both these years the reduction was

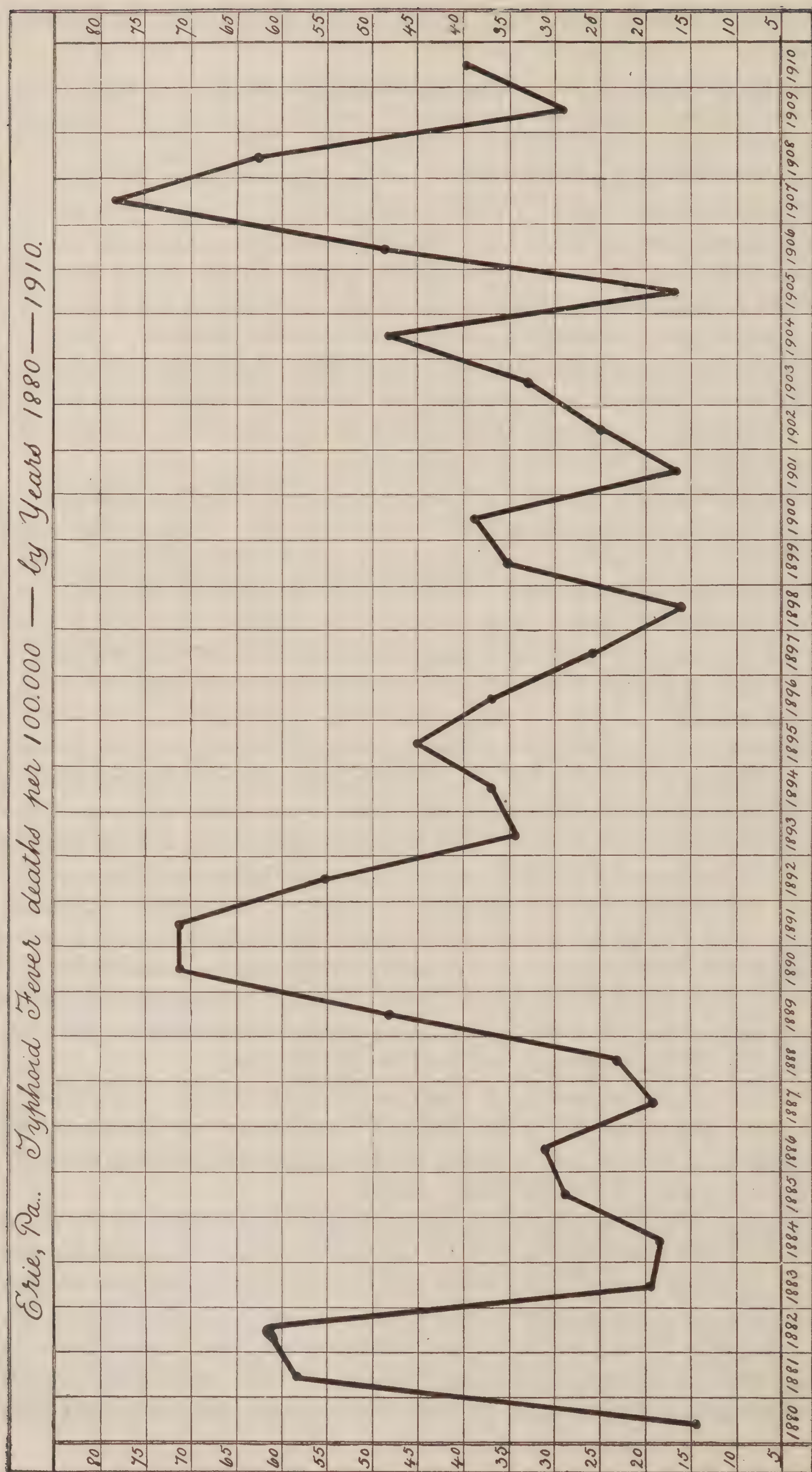



CHART XXVIII.

greatest in the months of January, February, and March. From 1906 to 1908 excessive rates again prevailed, due to the great number of cases in January, February, March, and April. In 1909 there was a drop to 29, due, as will be shown later, to a reduction in the usual number of cases in January, February, March, and April.

*Seasonal distribution of typhoid fever.*—The prevalence of winter typhoid in Erie is consistent and remarkable. The average for 10 years shows that January leads in number of cases, with February a close second, and that March and December both furnish more cases then September, the premier typhoid month in cities with good water supplies. In a period of 11 years only once has September furnished the largest number of cases, and that was in 1909, the first year in which Lake Erie water was used instead of the harbor water.

*Typhoid fever record in Erie, by months, 1901 to 1910.*

| Year. | Jan. | Feb. | Mar. | Apr. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1901 | 16 | 4 | 5 | 7 | 4 | 1 | 5 | 2 | 3 | 2 | 3 | 28 | 80 |
| 1902 | 59 | 46 | 17 | 8 | 6 | 3 | 6 | 10 | 10 | 8 | 4 | 12 | 189 |
| 1903 | 33 | 7 | 13 | 7 | 7 | 9 | 9 | 11 | 8 | 9 | 17 | 27 | 157 |
| 1904 | 18 | 39 | 33 | 41 | 27 | 20 | 15 | 2 | 13 | 4 | 2 | 12 | 226 |
| 1905 | 3 | 6 | 5 | 9 | 2 | 4 | 4 | 4 | 18 | 16 | 20 | 22 | 113 |
| 1906 | 30 | 20 | 25 | 10 | 14 | 5 | 6 | 3 | 5 | 10 | 10 | 8 | 146 |
| 1907 | 29 | 66 | 19 | 44 | 43 | 12 | 15 | 9 | 28 | 18 | 10 | 23 | 316 |
| 1908 | 69 | 44 | 23 | 20 | 14 | 15 | 10 | 8 | 22 | 27 | 12 | 17 | 281 |
| 1909 | 15 | 11 | 7 | 2 | 7 | 4 | 8 | 15 | 42 | 25 | 7 | 15 | 158 |
| 1910 | 5 | 17 | 48 | 7 | 9 | 3 | 3 | 18 | 38 | 26 | 15 | 31 | 220 |
| Total | 277 | 260 | 195 | 155 | 133 | 76 | 81 | 82 | 187 | 145 | 110 | 195 | 2,010 |

In 1910 March was the premier month, with 48 cases. In 1900, 1902, 1903, 1906, and 1908 January had the greatest number of cases. In 1907 February was first, with 66 cases. In 1904 April had the greatest number, and in 1901 and 1905 December headed the list.

Chart XXIX shows the excessive prevalence of winter typhoid in Erie during the past 10 years.

Chart XXX shows the curve for typhoid by months in Erie in 1909. The curve for 1909 is atypical for Erie, and resembles the typhoid curve of cities with good water supplies. It is the only year in the past decade in which the winter rise did not exceed that of September. The September total was high, but the yearly typhoid death rate was reduced from 78.4 in 1907 and 62.5 in 1908 to 29 in 1909, and the entire reduction was effected by the reduced number of cases in January, February, March, and April.

Chart XXXI shows the relation between the number of cases in January and February and the total cases for the entire year in the years from 1900 to 1910. The curves will be found to coincide until

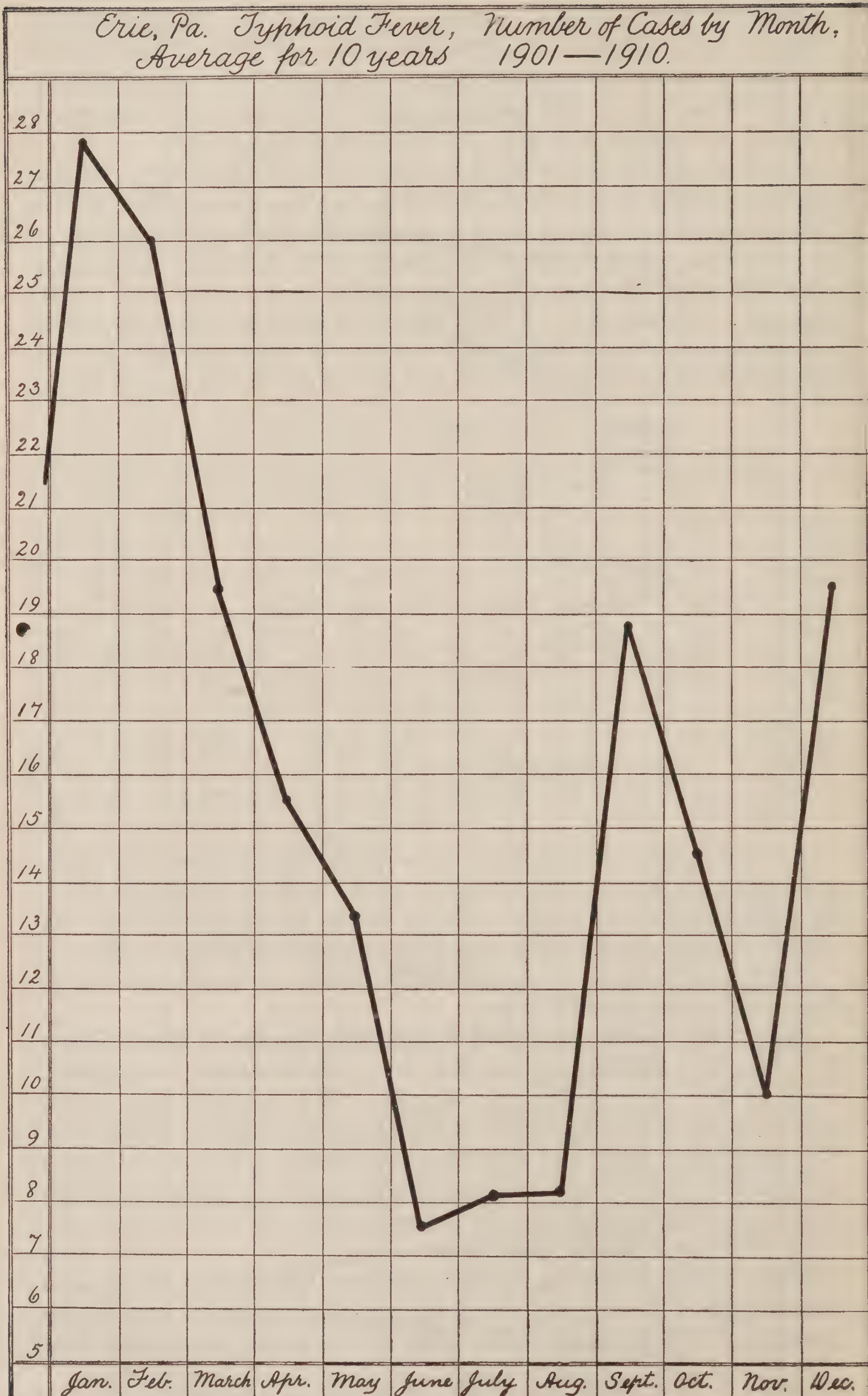

Erie, Pa. Typhoid Fever, Number of Cases by Month.
Average for 10 years 1901—1910.
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
Jan.
Feb.
March
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.

CHART XXIX.

1907, when the total case or yearly curve rises more sharply than that for January and February. This rise was not due to increase of typhoid cases in August, September, or October, but was due to an excessive number of cases in April and May. The only other lack of unanimity between the curves occurs in 1910, when the total yearly curve takes a sharp rise, while the curve for January and February is a trifle lower than 1909.

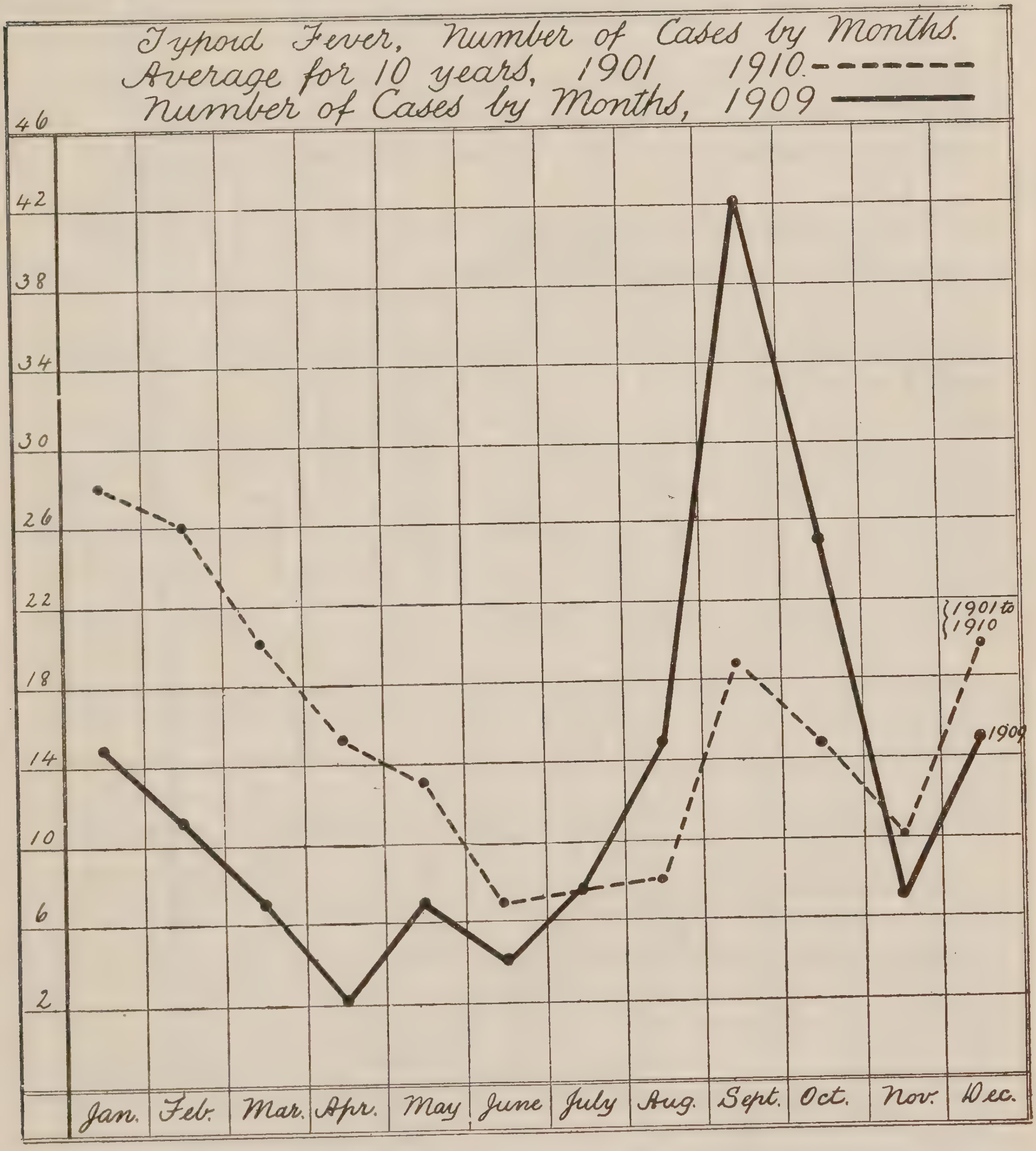



CHART XXX.

This is due to the very large number of cases in March, 1910, which, if added to the January and February curve, would bring it again into a normal relation with the curve for the entire year.

Chart XXXII shows the number of cases in August and September compared with the total for the entire year during the years from 1900 to 1910. The lack of relation between the curves is apparent in sharp

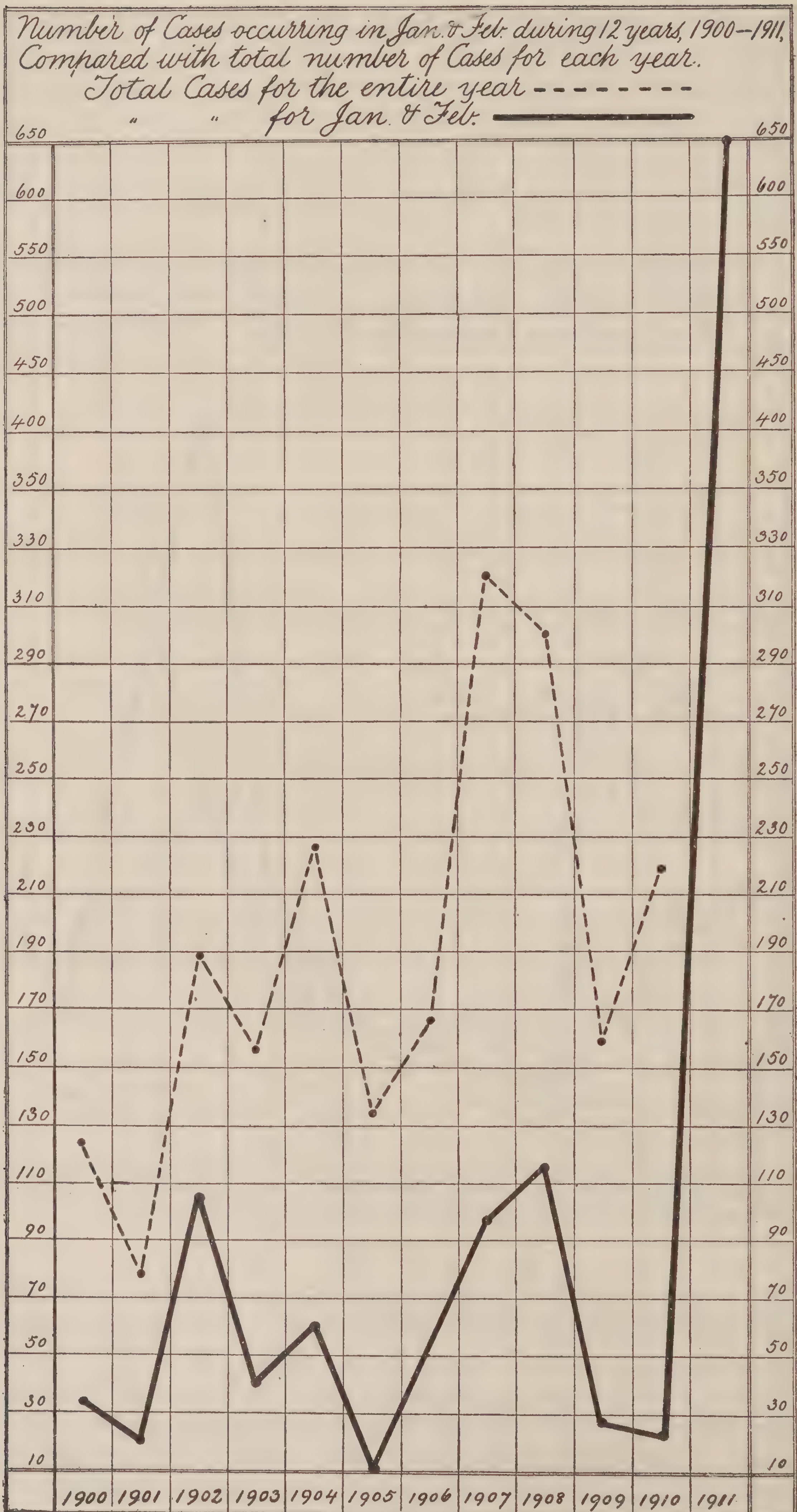

Number of Cases occurring in Jan. & Feb. during 12 years, 1900--1911,
Compared with total number of Cases for each year.
Total Cases for the entire year
" " for Jan. & Feb.
650
600
550
500
450
400
350
330
310
290
270
250
230
210
190
170
150
130
110
90
70
50
30
10
1900 1901 1902 1903 1904 1905 1906 1907 1908 1909 1910 1911

CHART XXXI.

distinction from the preceding chart which showed a very close relation between the curve for January and February and that of the entire year. Chart XXXII shows that the sharp rise in total cases for the year in 1902 and 1904 was not accompanied by a rise in the August and September curve. In 1905 there is a marked drop in the total cases for the year and a rise in the August and September cases. The same antagonism between the curves is evidenced in 1906, when a rising yearly curve is accompanied by a falling curve for August and September.

Again in 1909 there is a sharp rise in the August and September curve, while a big drop occurs in the total cases for the year. In 1910 there is a rise in the total yearly curve, while the August and September curve falls slightly.

These two charts (XXXI and XXXII) illustrate graphically the fact that increase in the yearly typhoid prevalence as shown by a sharp rise in the yearly curve is due to increased number of cases in January, February, or months other than August or September, and that reductions shown by a marked fall in the yearly curve are effected because of a reduction in the total cases for January and February, and often this yearly reduction is effected in spite of an increase for August and September. It has been generally accepted that excessive prevalence of typhoid fever in the winter months means waterborne infection. This is especially true if the number of cases in these winter outbreaks exceeds the number of cases in August, September, and October, when conditions exclusive of water are most favorable for typhoid.

Garbage and flies can be dismissed from consideration at once as factors in the causation of winter typhoid epidemics. Contact infection is always a factor in typhoid fever epidemics, and indeed this factor may even be very active in winter because of the greater crowding together in small rooms due to severe weather. But contact infection is augmentative rather than initiative in its action, and is a factor which gradually increases an existing epidemic or is responsible for the persistence of an epidemic which primarily was due to another cause. The increase due to contact infections is always gradual and progressive up to a certain point, when, if no new factors are introduced, the decline is correspondingly gradual.

The effect of substituting a filtered water for polluted water upon the prevalence of typhoid fever is shown by Chart XXXIII, taken from the annual report of the Albany water department for 1910. This effect is manifested in two ways: (1) An enormous decrease in the total number of cases; (2) change in greatest prevalence from winter and spring months, with a polluted water supply, to the autumn months, with a filtered water supply.

The figure is made from the average monthly cases for the nine years preceding and the nine years subsequent to filtration.

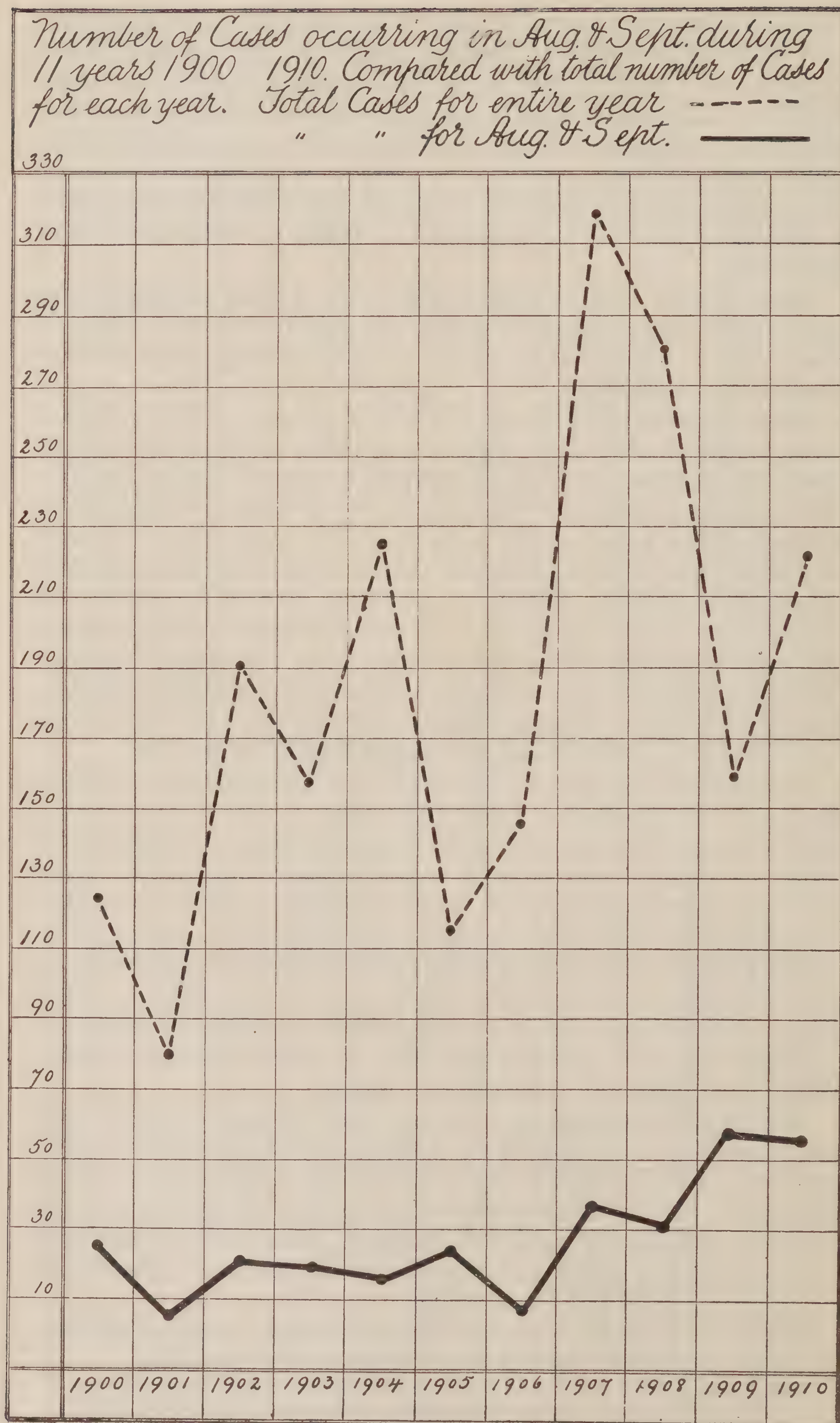

Number of Cases occurring in Aug. & Sept. during 11 years 1900 1910. Compared with total number of Cases for each year. Total Cases for entire year
" " for Aug. & Sept.
330
310
290
270
250
230
210
190
170
150
130
110
90
70
50
30
10
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910

CHART XXXII.

Water-borne epidemics are more sudden and often explosive in their onset, although the decline may be gradual owing to the secondary influence of contact infections. Types of the gradually ascending curve of contact typhoid may be noted in any city with a high typhoid rate and a good water supply.

Chart XXXIV shows the sudden onset of an outbreak in February, 1907, in Erie, Pa.

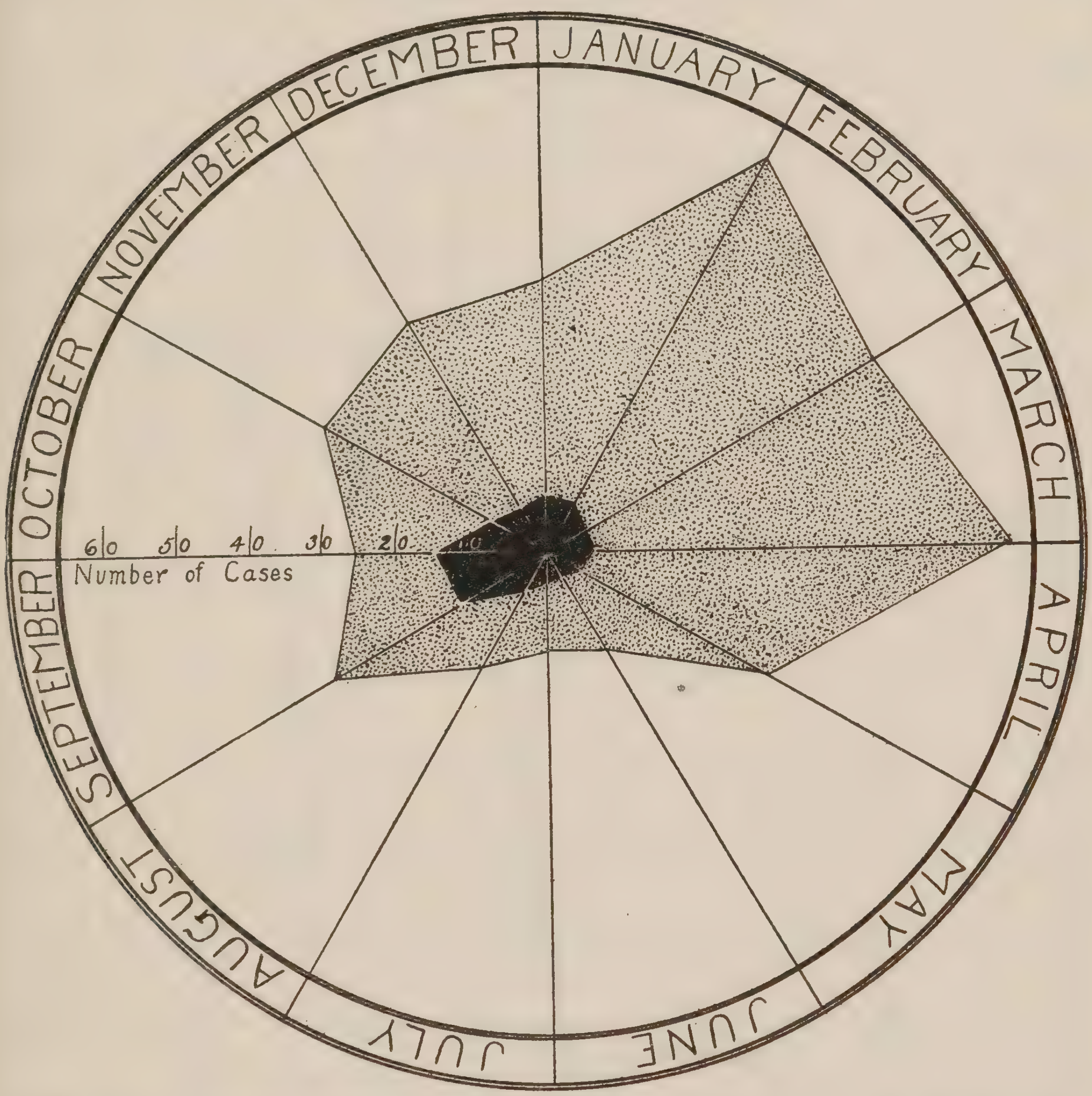



CHART XXXIII.—Showing seasonal distribution of typhoid fever, Albany, N. Y., for nine-year period before and nine-year period after filtration. The stippled area represents typhoid previous to filtration; the black area represents typhoid after filtration. (From the 1910 report of the Albany water department.)

Chart XXXV shows the sudden onset of an outbreak in January, 1908, in the same city.

Milk can be eliminated as a cause of annual winter outbreaks for several reasons. A milk epidemic might occur in January, February, or March, but it is much more likely to occur in warmer weather, and can not be charged with annual outbreaks in January and February covering a long period of years. The distribution of cases in a milk

epidemic is peculiar, and will be found to follow closely the milk routes involved. The distribution of cases in a waterborne outbreak will be

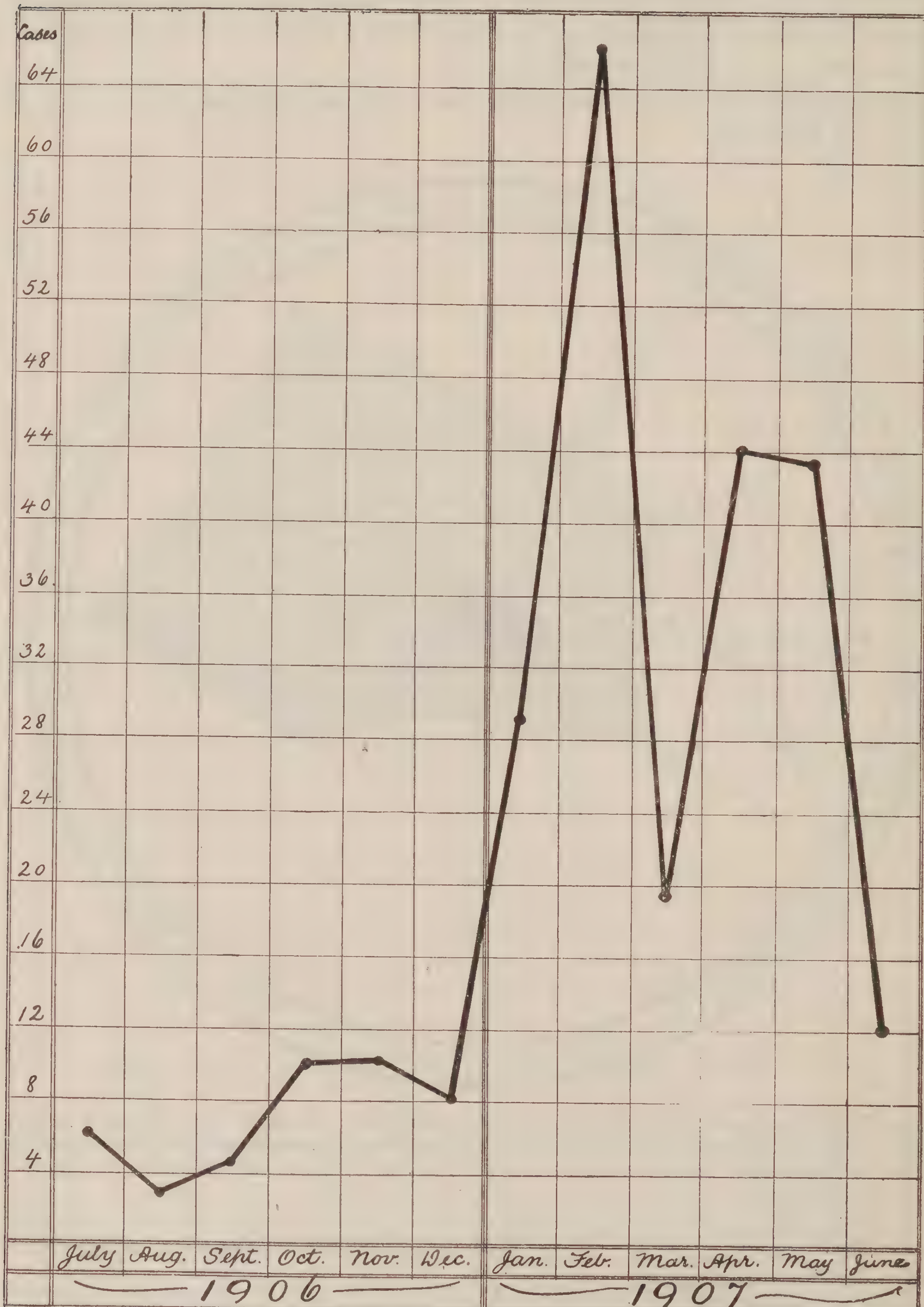



CHART XXXIV.—Erie, Pa., typhoid fever, showing explosive outbreak in February, 1907.

found evenly distributed according to the more or less general use of the water supply.

If we accept the number of cases in January and February as an index of waterborne typhoid, it will be noted that from 1902 to 1908,


CHART XXXV.—Erie, Pa., typhoid fever, showing explosive outbreak in January, 1908.

in these two months, the number of cases was always 40 or over with the exception of the year 1905.

*Typhoid fever cases in January and February, 1902 to 1911.*

| Year. | Number of cases. | Year. | Number of cases. |
|---|---|---|---|
| 1902 | 105 | 1907 | 95 |
| 1903 | 40 | 1908 | 113 |
| 1904 | 57 | 1909 | 26 |
| 1905 | 9 | 1910 | 22 |
| 1906 | 50 | 1911 | 660 |

In 1905 the people of Erie were drinking the same dilute sewage as in 1904 and 1906. The only inference possible in considering the paucity of cases in 1905, and especially in January and February, is that during the preceding months there must have been less typhoid excreta going into the bay. As a matter of fact, there were only 18 cases of typhoid in Erie in the three months preceding January 1, 1905, while the average for these months for 10 years was 44 cases.

There was a good deal of typhoid in Erie in the regular typhoid season of August, September, and October, in 1910. The 10-year average for these months was 41 cases. The cases in August, September, and October, 1910, totaled 82, or exactly double the usual number; in November there were 15 cases and in December 31; so that there was plenty of typhoid excreta going with the sewage to the harbor in the closing months of 1910.

TYPHOID FEVER EPIDEMIC OF JANUARY AND FEBRUARY, 1911.

The typhoid outbreak of January and February, 1911, was of an explosive character and presented a total of over 700 cases. The records of the city board of health, by months, from July, 1910, to February, 1911, show cases of typhoid fever reported as follows:

| | | | |
|---|---|---|---|
| July, 1910 | 3 | November, 1910 | 15 |
| August, 1910 | 18 | December, 1910 | 31 |
| September, 1910 | 38 | January, 1911 | 240 |
| October, 1910 | 26 | February, 1911 | 514 |

Chart XLII shows the very sudden onset of the outbreak. This chart, made from the records of the local board of health, probably fails to do justice to the extreme explosive character of the outbreak. Mr. F. Herbert Snow, chief engineer of the Pennsylvania department of health, who took charge of the outbreak about February 1, made a careful census of the cases with regard to the onset of the initial symptoms. From this canvass he was forced to revise the dates of onset, so that many of the February cases were set back to January, where, in reality, they belonged, bringing the apex of the epidemic in January and greatly shortening the period of time between the beginning and the highest point in the epidemic.


MAP 9A.—Erie, Pa., showing location of cases of typhoid fever reported from January 1 to February 15, 1911. Five hundred and seventeen houses are indicated on the map by black dots. From these 517 houses 531 cases of typhoid fever were reported to the board of health in the above period.

*Cause of the outbreak.*—The season practically excludes flies as a factor in causation. Very little ice is used in private houses in the winter season. Less vegetables are eaten, and flies, vegetables, and ice need not be considered further as prominent factors in this massive outbreak.

The season is also against contact infection. Outbreaks in which contact plays the principal rôle are apt to be most common in summer or early autumn, although a low rate of prevalence of typhoid may be maintained throughout the winter months by contact, due to the crowding together and more intimate relation of individuals in severe or inclement weather.

In the six weeks from January 1 to February 15, 531 cases of typhoid fever were reported at the health office. These 531 cases occurred in 517 houses, distributed on Map 9A as black dots.

Only 14 times in this period did a second case appear in the same house, according to the official figures. In regard to the incidence of typhoid in the general population during this period it may be said that 1 person in 125 contracted the fever. Rating the population of the infected houses as 2,068, or 4 persons in each family, the incidence among these people exposed to known infection was only 1 person in 147; a rate slightly less than that of the general population. This indicates that contact played no appreciable part in the primary outbreak (January 1 to February 15).

Typhoid rates under these winter conditions due to contact are certain to be lower than those of the warm months, when flies and other factors are more prominent. It is inconceivable that contact could cause an explosive outbreak which showed over 600 cases in six weeks.

Contact outbreaks, even in a favorable season, show a gradual rise and are prone to show an uneven distribution, with secondary cases, in the same houses or group of houses and more or less defined foci of infection.

The Erie outbreak of January and February, 1911, was sudden in its onset and explosive in character. The map showing the distribution of infected houses from January 1 to February 15 proves the even distribution of the cases and the absence of clearly defined local foci of infection. It further shows that during this first six weeks of the outbreak secondary cases were few, as these 517 houses represented only 531 cases.

As pointed out in earlier pages, the insanitary conditions due to lack of proper garbage collections and the filthy outdoor closet are in need of correction. That these may be factors, especially when flies are prevalent, in the spread of typhoid fever, is beyond question, but they could not have played any considerable rôle in the transmission of typhoid in January and February, 1911.

The characteristics of a milk outbreak were absent during the January and February outbreak in Erie. Fairly even distribution among 66 milk distributors in itself almost excludes milk as a factor. One distributor, the Erie Milk Association, had, as might be expected, a large number of cases on its routes, but this association distributes about 50 per cent of the milk used in Erie. The proportion of children attacked was not disproportionate, and more than one case in the same house was not common. Many of the sick gave a history of having used no milk whatever. No case of typhoid fever has been reported for many months from Erie County, which furnishes practically all of Erie's milk.

The city health officer, Dr. J. W. Wright, is also State inspector for Erie County, and is reasonably confident that no typhoid existed among the dairy farmers of Erie County and certain that no deaths from the disease occurred within the year previous to the outbreak.

After having eliminated ice, vegetables, flies, contact, insanitary privies, garbage, and milk as prime factors in the causation of this particular outbreak of January and February, 1911, there remains but one factor which can be charged with the responsibility of its production.

In considering water as a cause of the outbreak it is only necessary to consider the public supply of the city of Erie, as wells in Erie are very scarce, and the public supply is generally used. That water was the cause of the outbreak can scarcely be doubted after a consideration of all the facts.

The season is a common one for waterborne epidemics. The sudden onset is characteristic of waterborne typhoid. The very large number of cases in a short time suggest water. The even distribution over a large area is characteristic of a water outbreak. The presence of these facts pointing to water and the absence of conditions favorable to and characteristic of outbreaks due to other causes leave no escape from the conviction that water was entirely responsible for the explosive part of the outbreak.

It must not be inferred from this that other factors played no rôle in the spread of the disease. Contact infection plays a rôle in nearly all epidemics. Milk was surely responsible for some cases, but these factors were incidental and secondary rather than primary, and it may be accepted that water was the prime factor and directly responsible for the outbreak.

Was there direct evidence of sewage pollution of the water supply at the lake intake? Unfortunately no examinations were made until after the epidemic was well under way. Mr. F. Herbert Snow, chief engineer of the Pennsylvania State department of health, was in charge of the suppressive measures taken by the State and took charge in Erie at the end of January. He very kindly furnished

the writer with the bacterial counts and *B. coli* estimation from January 28 to February 22. These were made from samples taken from the water at Presque Isle before it passed under the polluted harbor and at the pumping station after it had passed the opportunity of pollution from a leaky pipe. The counts were as follows:

| Date collected. | Presque Isle. | | Pumping station. | |
|---|---|---|---|---|
| | Total bacteria in 1 c. c. | B. coli. | Total bacteria in 1 c. c. | B. coli. |
| Jan. 28 | ---------- | -------- | ---------- | -------- |
| 29 | 24 | 0 | ---------- | -------- |
| | 20 | 0 | ---------- | -------- |
| 30 | 12 | 0 | 16 | 0 |
| | 20 | 0 | 30 | 0 |
| 31 | 20 | 0 | 16 | 0 |
| | 28 | 0 | 42 | 0 |
| Feb. 1 | 32 | 0 | 10 | 0 |
| | 12 | 0 | 40 | 0 |
| 2 | 24 | 0 | 60 | 0 |
| | 14 | 0 | 12 | 0 |
| 3 | 200 | 0 | 0 | 0 |
| | 100 | 1 | 0 | 0 |
| 4 | 60 | 3 | 34 | 0 |
| | 36 | 0 | 16 | 0 |
| 5 | 300 | 0 | 800 | 0 |
| | 600 | 0 | 180 | 0 |
| 6 | 10 | 0 | 22 | 1 |
| | 6 | 0 | 24 | 0 |
| 7 | 88 | (?) | 20 | (?) |
| | 212 | (?) | 80 | (?) |
| 8 | 10 | 0 | 32 | 0 |
| | 20 | 1 | 10 | 0 |
| 9 | 40 | 0 | 56 | 0 |
| | 30 | 0 | 60 | 2 |
| 10 | 28 | 0 | 120 | 0 |
| | 70 | 0 | 80 | 4 |
| Feb. 11 | 12 | 0 | 630 | 0 |
| | 22 | 0 | 240 | 6 |
| 12 | 24 | 0 | 700 | 0 |
| | 20 | 0 | 32 | 0 |
| 13 | 40 | 0 | 20 | 0 |
| | 20 | 0 | 80 | 0 |
| 14 | 12 | 0 | 8 | 0 |
| | 16 | 0 | 12 | 2 |
| 15 | 84 | 0 | 84 | 1 |
| | 48 | 0 | 14 | 0 |
| 16 | 16 | 0 | 8 | 0 |
| | 112 | 0 | 22 | 0 |
| 17 | 180 | 1 | 0 | 0 |
| | 160 | 0 | 0 | 0 |
| 18 | 60 | 0 | 14 | 0 |
| | 260 | 0 | 280 | 0 |
| 19 | 350 | 0 | 20 | 0 |
| | 2,400 | 0 | 24 | 0 |
| 20 | 40 | 0 | 0 | 0 |
| | 16 | 0 | 0 | 0 |
| 21 | 84 | 0 | 0 | 0 |
| | 4 | 0 | 0 | 0 |
| 22 | 20 | 0 | 0 | 0 |
| | 10 | 0 | 0 | 0 |

These figures do not show gross pollution at the intake during February, but if pollution through the lake intake caused the outbreak, it must have taken place during December or early in January, when, unfortunately, no bacterial counts were made.

However, it will be noted that *B. coli* was present in the water at the intake on the 3d, 4th, 8th, and 17th of February. The figures do not show any marked or consistent differences between examination of water before and after it had passed under the polluted harbor.

If the 60-inch steel main carrying the water under the harbor had a significant leak, there should be a marked increase in the bacterial count and in the *B. coli* found at the pumping station; such leak not having been repaired, this difference should be consistent and the

counts should be continuously higher This is not the case. There are slight differences, but they are within the index of error, as shown by differences in two samples from the same place upon the same day. Further, these marked differences occurred but seldom.

It is clear, then, that the sewage pollution must have reached the mains by way of the lake intake. The question is, How did this take place?

In November considerable dredging was done in Erie Harbor under the direction of the United States engineer in charge. About 90,000 cubic yards of filthy muck was removed from near the mouth of Mill Creek and dumped a few miles east of Erie, near the mouth of Four-mile Creek. This material was the accumulation of years brought down by Mill Creek, and consisted largely of sewage solids, Mill Creek in dry weather receiving about 8,000,000 gallons of sewage daily.

What effect this material had on the water supply, if any of it reached the intake, can only be conjectured. The great bulk of this material was not fresh sewage; in fact, the sewage elements were largely in a septic condition. It was dumped at a considerable distance to the eastward, with opportunity for dilution. This dumping can not be considered to have been entirely free from danger, and it is quite possible that some of it did reach the intake, carried by currents from the east.

This may not have had anything to do with the typhoid outbreak, and it must be remembered that gross sewage pollution could take place direct from the harbor under certain weather conditions independent of dredging or dumping operations.

*How gross sewage pollution of the intake could take place.*—Erie Harbor, or Presque Isle Bay, contains about 15,000,000,000 gallons of water. Erie pours into this landlocked harbor 11,000,000 gallons per day of house sewage. This is a conservative estimate and is based upon data secured by the city engineer of Erie during a protracted drought, when storm water water was not a factor. This means that if the city of Erie discharges its sewage into the bay for one day in the year, the proportion of sewage to bay water would be 1 to 1,250.

In one year the total amount of house sewage exceeds 4,000,000,000 gallons, or 26 per cent of the total capacity of the harbor. The normal outflow from the bay to the lake in good weather is a volume of water equivalent to the run-off from the 26 miles of watershed plus the discharge from the sewers. This amount of water in good weather is apt to be less polluted than water near the sewer outfalls, because under these conditions Presque Isle Bay acts as a sedimentation basin, and, even if grossly overworked, exercises considerable purifying action upon the sewage-polluted water entering it.

It is under weather conditions such as those which pertain in the summer months—tranquil weather, slight rainfall, and light winds—that we have the least number of cases of typhoid fever in Erie. These conditions are unfavorable to the gross pollution of an intake in the lake which is placed several miles to the westward of the harbor entrance because of the lessened discharge from the bay, the greater degree of sedimentation and other purifying agencies which take place in the harbor under these conditions, and the greater prevalence of normal lake currents tending to carry pollution away from the intake.

Contrast these conditions with those of stormy weather. The sedimentation is interfered with, and a greatly increased volume of sewage-polluted water, upon which little if any purifying action has been exerted, is poured through the harbor entrance into the lake.

The surface area of Presque Isle Bay is about 160,000,000 square feet. Under storm conditions the level of the bay has been known to rise 3 feet and to afterwards fall the same distance. A fall of 1.5 feet has been noted within 10 hours. This means that 240,000,000 cubic feet of grossly polluted water is poured through a 300-foot channel in the short space of 10 hours.

This rush of water through the harbor entrance creates sufficient current to carry the pollution well out from shore, where it is picked up and carried in a direction depending upon the direction of the lake current itself. This naturally brings us to the following questions: First. What is the direction of Lake Erie currents? Second. Are there currents from east to west which could carry sewage-polluted water from the harbor to the waterworks intake? Third. Under what conditions is a current from east to west caused? Fourth. Did these conditions exist during December or January?

*Direction of Lake Erie currents.*—Lake currents are notoriously unstable. This instability is particularly true of Lake Erie, because of its comparative shallowness and exposure to strong wind action. The normal movement in the lake water, which can scarcely be called a current, is roughly from southwest to northeast, at a rate of only from one-sixth to one-half mile per day.

From the writer's observations and study of data kindly furnished by the United States Weather Bureau, it seems probable that several distinct combinations of conditions may produce currents of considerable velocity from east to west passing over the intake of the Erie waterworks.

This view is further supported by the local forecaster at Erie, Mr. Oberholtzer, in a scholarly paper [1] prepared by him upon this subject,

[1] Oberholtzer, G. R., The Currents of Lake Erie; the Possible Cause of the Contamination of the Water Supply of the City of Erie by Sewage Discharged into the Harbor. Report made to the Chief, U. S. Weather Bureau, February, 1911.

a copy of which he very kindly furnished me. Mr. Oberholtzer's data are above reproach, but in my opinion he overlooks the importance of the compensatory undercurrent which follows gales or strong winds from the southwest quadrant blowing continuously, and from an epidemiologic viewpoint lays too much stress on the currents from east to west caused by winds from the northeast quadrant.

The following combinations are all capable of furnishing a distinct lake current from east to west, and are placed by the writer in the order of their importance as a cause of gross pollution of the Erie intake: (1) Gales or strong winds from the southwest quadrant continuing for several days; (2) gales or strong winds from the southwest quadrant for less than 48 hours, with sudden change of wind to northeast quadrant; (3) gales or strong winds from the northeast quadrant, continuing for several days; (4) gales or strong winds from the northeast quadrant for less than 48 hours, with sudden change to southwest quadrant; (5) moderate or mild winds from the northeast quadrant continuously for several days.

*Gales or strong winds from the southwest quadrant continuing for several days.*—Gales from the west or southwest blowing for several days are capable of raising the lake level at Buffalo to a height of over 6 feet above normal. This probably means that there is a drop below normal at Amherstburg of over 5 feet. The surface level of Lake Erie at such a time is, roughly speaking, an inclined plane. The Buffalo end of this plane is 12 feet higher than the end at Toledo. During this stage of high water at Buffalo the height of water in Erie harbor is probably 3 feet above normal. If the same strong winds or gales continue to blow, the water at Buffalo does not continue to rise above 6 feet, in spite of the fact that an enormous volume of water is being carried toward Buffalo by a surface current traveling with the wind. The water at Buffalo not only does not rise above the high-water mark, but, in spite of continuance of wind from the southwest, falls rapidly toward the normal.

The falling stage of water at Buffalo in spite of a strong wind-induced surface current toward Buffalo, coupled with the rising of the water toward the normal at Toledo, and an equalization of the level of the lake from end to end, shows clearly that an enormous volume of water has returned to the western end of the lake; and inasmuch as the surface current has been eastward, this enormous bulk of water must have returned by an undercurrent. As this equalization of the lake level is sometimes effected very rapidly, the velocity of the undertow westward is correspondingly great.

*Conditions which favor increased velocity of Lake Erie currents at Erie, Pa.*—Lake Erie may be divided into three portions. That portion west of a line drawn due south from Point Pelee is shallow, contains numerous islands, and is unimportant in considering cur-

rents at Erie. The other two portions are really two basins divided by a line drawn due south from Port Rowan, Canada, to a point a few miles west of Erie. Lake Erie's length is about 250 miles and its maximum width 60 miles. These two basins are further separated by the constriction in the lake outline produced by the projecting of Long Point into the lake a distance of 20 miles. In fact, the width of the lake is here reduced to only 28 miles.

The eastern basin has a depth of 200 feet, as the contour map will show slopes gradually upward from its deepest part to the depth of about 60 feet. By referring to the contour map the divide which evidently in remote ages separated two distinct bodies of water may be distinguished, and this divide was crossed by a narrow channel which exists to-day and may be made out as a deeper portion about 6 miles north of Erie, and is well known to the fishermen, who call it the "canal." This channel carries the bulk of the water returning westward to equalize the lake level after strong west or southwest winds, or water going westward because of strong east or northeast winds.

The western basin is much wider and longer than the eastern, but a great deal shallower, having a maximum depth of about 85 feet. The constriction here in itself in the absence of very great depth would account for increased velocity of currents passing Erie, but the question of depth is here very important in accentuating this velocity. The depth on the imaginary line separating the two basins is nowhere deeper than 13 fathoms, except in the "canal" just northwest of Erie. The channel is indicated roughly on the contour map (chart XXXVI) by the long, narrow loop from east to west formed by the 13-fathom contour. With a sudden rise in lake level at one end and an equally sudden fall at the other and in the equalization which follows this disturbance of levels,we have currents of greatly increased velocity passing at Erie through a comparatively narrow and shallow channel.

Attention is called to the cross section at C, a few miles west of Erie. This cross section shows two peculiarities: (1) It is the shallowest of the four cross sections shown in the diagram; (2) its deepest portion is only a few miles north of Erie.

The great reduction in the cross section at C means enormously increased velocity in the deeper part of this shallow cross section, viz, just north and west of Erie.

It is interesting to speculate upon what takes place in Erie Harbor while the fall to the normal at Buffalo after such abnormally high water is being effected by a westward current.

The fall from high-water mark in Buffalo means a corresponding drop in Erie Harbor, and this has been known to take place within a few hours. What is taking place when such a combination of

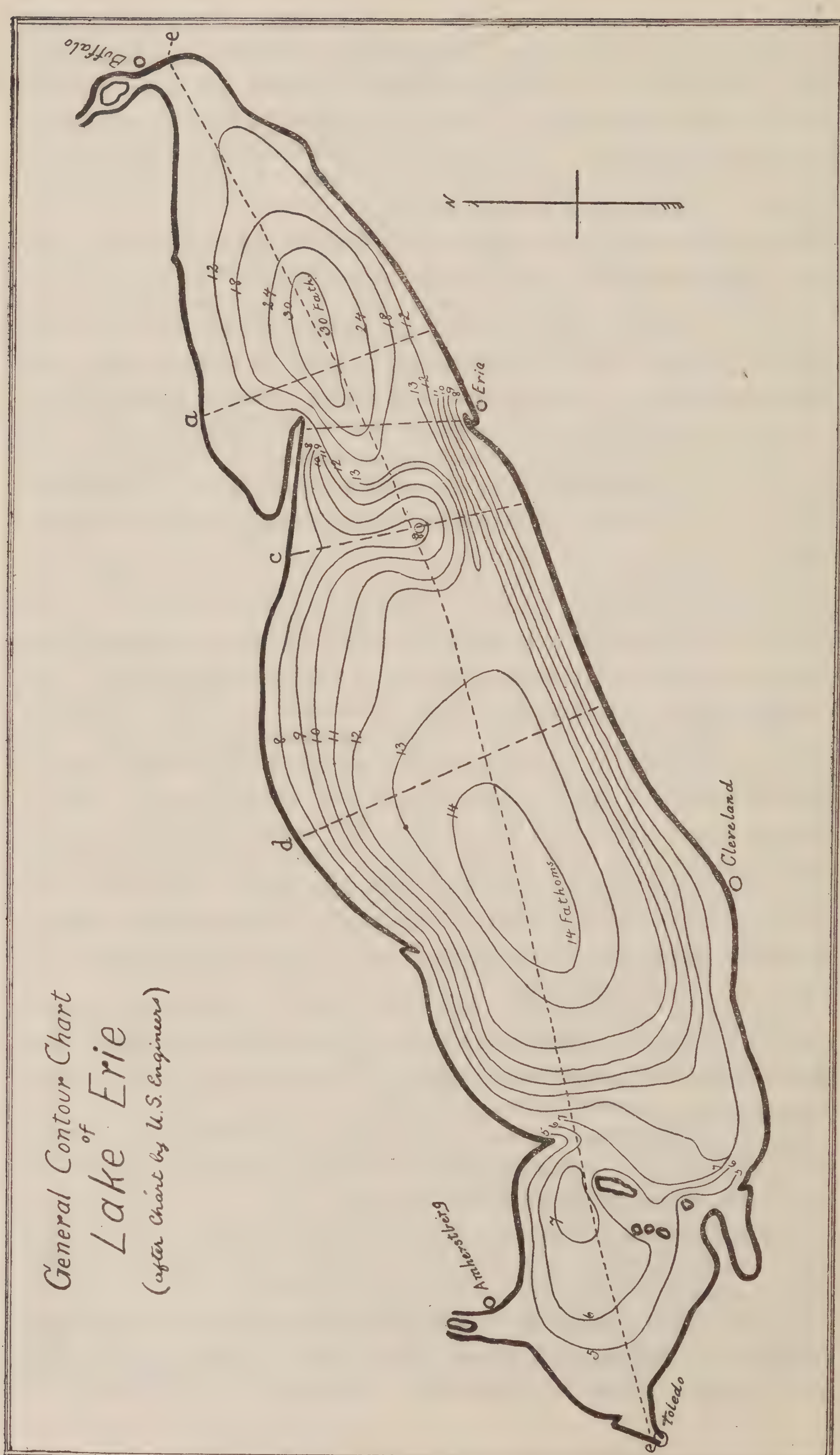

General Contour Chart
of
Lake Erie
(after Chart by U.S. Engineers)
Buffalo
Erie
Cleveland
Toledo
Amherstberg
30 fath.
14 Fathoms
N
a
c
d
e

CHART XXXVI.

circumstances exists? With a drop of 1½ feet 240,000,000 cubic feet of sewage-laden water is poured out of the harbor entrance into the lake current bound westward past the waterworks intake. That such a current operates at times is supported further by the testimony of fishermen. These men place their nets at the bottom of the lake, in what is known as the canal, a portion of the lake 5 or 6 miles north of Erie. They report that at times this undertow is so great that their nets are carried far to the westward and that the meshes of the nets are clogged with filth and débris of all kinds.

From the foregoing it is clear that strong winds or gales from the southwest quadrant continuing for several days may produce a strong current westward in Lake Erie, and that at the same time a sudden pouring out of sewage-laden water from Erie Harbor to join this westward current takes place. The result of this is that gross sewage pollution of the intake may take place under these conditions.

*Gales or strong winds from the southwest quadrant for less than 48 hours with sudden change to the northeast quadrant.*—This combination of conditions resembles the first, except that the equalization of level in the two portions of the lake would be slightly more rapid, the surface current from east to west produced by the wind aiding in the process. If the northeast wind continued to blow, piling up of the water at Toledo and Amherstburg, the exact reverse of No. 1 would ensue.

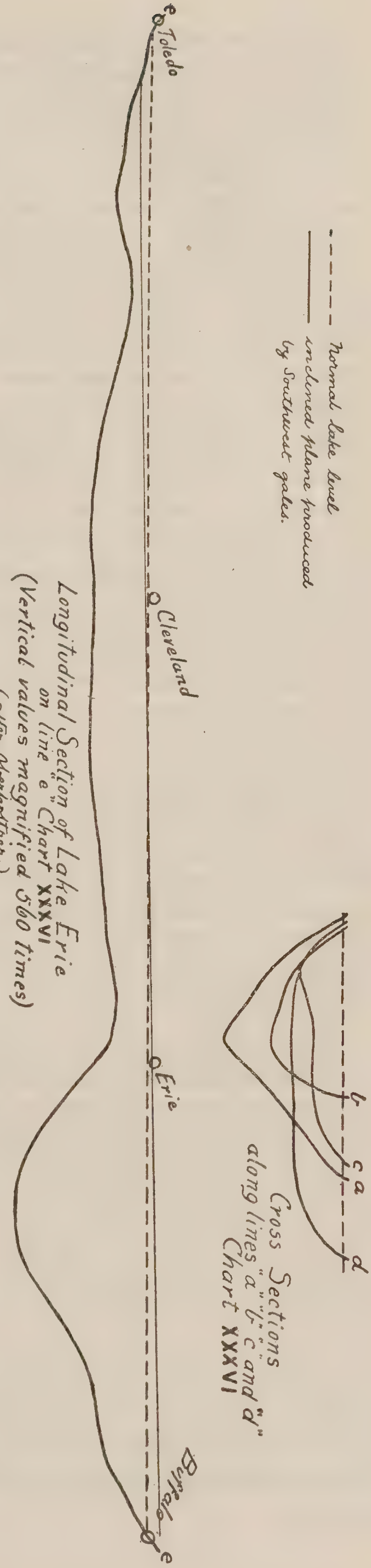



CHART XXXVII.—Longitudinal section of Lake Erie showing inclined plane produced on the lake surface by southwest gales. Cross sections showing the relative depths of Lake Erie at points *a*, *b*, *c*, and *d*. (After Oberholtzer.)

*Gales or strong winds from the northeast quadrant continuing for several days.*—Gales from the northeast blowing for several days would cause piling up of the water at Toledo, a strong surface current from northeast to southwest, fall in the water at Buffalo and Erie, and pouring out of a large volume of sewage-polluted water from Erie Harbor into the prevailing current. The amount of the sewage-polluted water thus poured out which is carried westward by the surface current past the intake depends upon the depth of the surface current. This would vary according to the length of time during which the northeast winds had prevailed. During the first violence of a northeast gale some of this sewage-laden water might well be carried with the surface current westward far enough below the surface to enter the intake. After high-water mark is reached at Toledo and equalization of the lake level is commenced the undercurrent setting toward the northeast would probably carry the bulk of the polluted water from the harbor away from the intake. A portion of the polluted water even at this stage would be carried westward by the surface current over the position of the intake if the wind still continued to blow from the northeast or east, and the only protection the intake would have against pollution from this surface current would be the rather insecure one of its depth below the surface.

*Gales or strong winds from the northeast quadrant for less than 48 hours, with sudden change to the southwest quadrant.*—This condition would produce a strong surface current from east to west past the intake—a pouring out of the sewage-polluted contents of Erie Harbor because of lowering of the harbor-water level and then a very rapid return toward the normal, the beginning undertow from west to east being assisted by the surface current, west to east caused by the change of wind.

This combination of conditions would give a very short period of sewage-polluted water carried over the intake by a surface current from east to west. After the first few hours of such a gale the deep compensatory undercurrent from west to east would begin to operate, and stratification would tend to prevent the polluted water in the surface current from reaching the deeply placed intake, which is in 26 feet of water. The surface current itself would be checked and reversed toward the east by the change of wind.

*Moderate to mild winds from the northeast quadrant blowing continuously for several days.*—In regard to the existence of currents from east to west due to the above combination, Mr. Oberholtzer proved conclusively that such currents exist by a series of observations made in the summer of 1910, from jetties extending from Presque Isle out into the lake. Mr. Oberholtzer describes his experiments as follows:

In the spring the prevailing westerly winds crowd the ice from the main portion of the lake into the eastern end and the water of the main shallow portion is warmed rapidly as summer approaches, enabling fishermen to begin operations in the west in April. They agree that by the end of June it is most improbable that the water in any portion of the lake west of the narrows is colder than 65°. In the eastern portion, where there is ice for a month or more after it has disappeared in the west, the water is colder, and, on account of its depth, remains colder than that west of the narrows throughout the year. The temperature readings taken in the deep portion of the lake by the Bureau of Fisheries confirm the belief that the water at the lowest levels is practically uniform throughout the year at about the temperature of water at its greatest density. The wide difference in temperature between waters east of Erie and those to the west should in itself disclose the source of lake currents, whether they flow from the uniformly warm, shallow main body or come from the colder eastern portion, where the temperature decreases steadily as the depth increases. The approximate strength of an easterly current would be indicated by its temperature, for only strong currents generated on the surface could disturb the deeper water. On June 24 and 25 the wind movement averaged 12 miles an hour from the northeast for 44 hours.

The temperature of the water at jetty No. 3 fell from 70° to 64° in 24 hours, and then rose slowly to 71° under the influence of moderate southwest to west winds by the 3d of July. On the 4th of July the wind again became northeast and varied little from that direction for 40 hours, with an average force of 13 miles per hour. The water temperature fell from 71° on the morning of the 4th to 60° on the morning of the 5th. Under the influence of southerly to westerly winds, varying from 6 to 15 miles per hour, it rose to 73° on the 10th. A period of northeast winds began July 16, to which attention is called. The wind shifted to northeast shortly after 3 p. m. July 16 and soon became brisk. By 8 a. m. of the 17th the water at jetty No. 3 had fallen to 59° and at the intake to 56°. The wind continued brisk northeast until 8 a. m. of the 18th (excepting a period of east winds early on the 18th) when the temperature at both intake and jetty had fallen to 54°. By the evening of the 18th the wind had become light, but it continued in a generally northeasterly direction of small movement until midnight of the 19th. After this time the wind was southerly to westerly for days. The temperature of the water at the intake did not return to normal until the 23d. The conclusion seems inevitable that the cold water about jetty No. 3 and the intake in the lake, occurring only during east and especially northeast winds, is carried from the only place in the lake where such low temperatures are found in midsummer, viz, the deep eastern portion.

It follows also that the current moving westward on this occasion was of sufficient volume and velocity to bring up water that was 18° colder than that at the surface. It appears that this cold water was carried far to the westward, for, in spite of the heating of this water in a July sun in relatively moderate depths surrounded by warmer water, the temperature at the intake did not return to normal until the 23d, after a total wind movement of almost 1,000 miles from the south and southwest had driven the cold water back eastward of the intake (or was it warmed and remained for even a longer period about the intake?). In this case the intake was evidently surrounded for more than six days by water brought along the shore from the lake east of Erie. The westward flow of these currents is undoubtedly promoted by the deep channel found in the lake west of Erie.

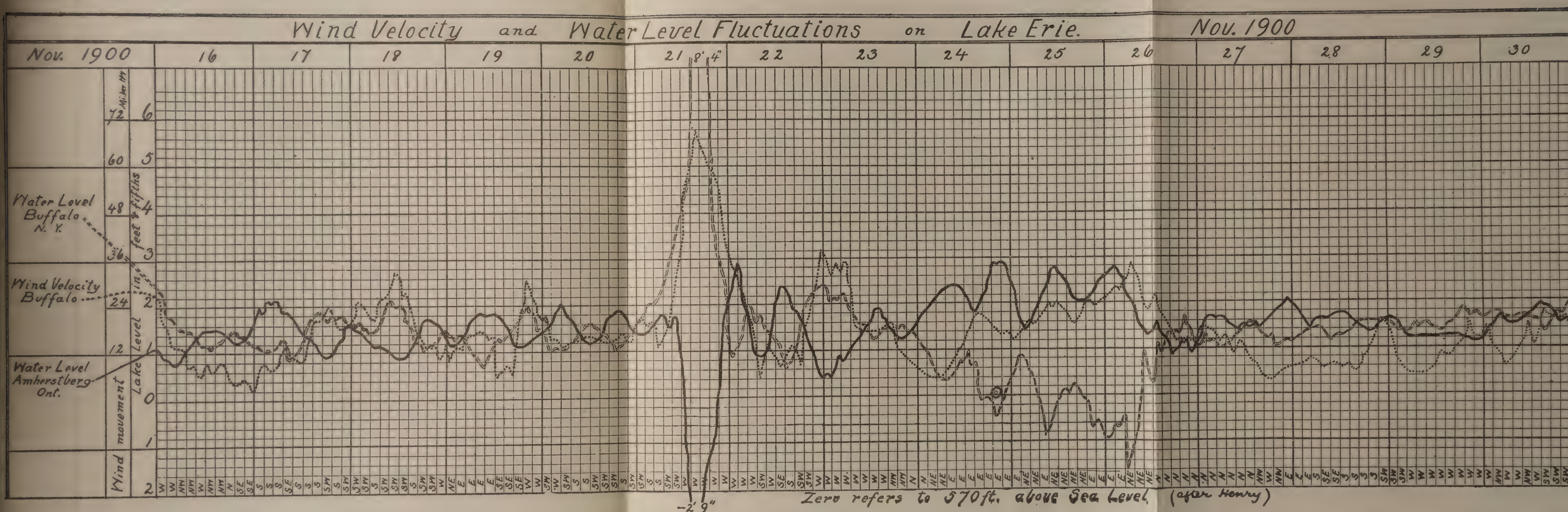
While the five distinct combinations of wind conditions and probably other combinations are all capable of producing a current from east to west past Erie's waterworks intake, several points combine to make No. 1 (gales or strong winds from the southwest quadrant

continuing for several days) the most important as a cause of sewage pollution of Erie's water supply. Under these conditions the fall in the level of the harbor is greater and more sudden than following any other combination of wind conditions. (See Charts XXXVIII, XXXIX, XL.)

It might be argued that west or southwest winds raise the level of the water in Erie Harbor, and so could be dismissed because a raising of level is inconsistent with a heavy discharge of sewage from the harbor. It might be argued further that when this discharge came after the high-water mark was reached that it would consist largely of the lake water which had entered the harbor while the level was raising and, consequently, was very much diluted. Neither of these arguments will bear close scrutiny. The first is only partially true. Moderate southwest winds do raise the level in Erie Harbor to a certain point, but when this point is exceeded the water falls again, so that with the second period of a strong wind or gale from the southwest there is a sudden drop in the level in Erie Harbor coincident with and proportionately less than the drop at Buffalo. As to the dilution effected by lake water entering the harbor, this is more apparent than real, as several days of moderate west winds maintain a high level in Erie Harbor partly by retention of the run-off and sewage inflow within the harbor and partly by the actual addition of fresh lake water. As an illustration of the result of a gale or strong winds blowing continuously for several days from the southwest quadrant, observe what happened in Buffalo November 21 and 22, 1900. (Chart XXXVIII.) On the 21st a gale from the southwest and west produced in a few hours a rise of water in Buffalo of over 6 feet.

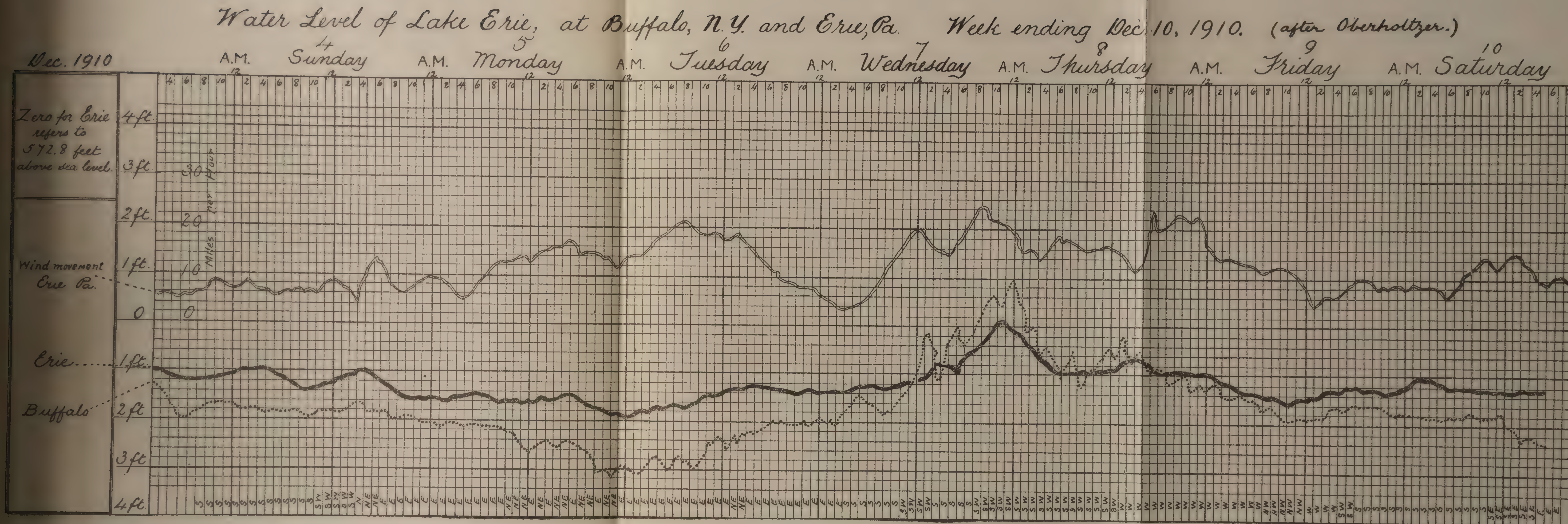
The water fell 6 feet immediately after, and early in the morning of the 22d was below normal in spite of the persistence of strong west winds. This drop at Buffalo would coincide with a drop in Erie of about 3 feet, which means a discharge of polluted water from Erie Harbor into the lake current of 480,000,000 cubic feet within a few hours.

Strong winds from the southwest blowing from noon Wednesday, December 7, 1910, produced a rise in Erie Harbor level of 1.3 feet in 11 hours, and within 7 hours, or at 6 a. m. Thursday, December 8, a drop of 1.2 feet had taken place coincident with a drop in Buffalo of over 2 feet in the same period, the wind persisting from the west or southwest all day Thursday and part of Friday, December 9. A further fall of over 1 foot (Chart XXXIX) took place between 4 p. m., December 8, and 10 a. m., December 9. Another striking example of the effect of winds from the southwest quadrant occurred on Sunday, January 8, and January 9. A southwest wind 20 to 30 miles per hour, from 5 p. m. to 10 p. m., Sunday, January 8, effected a rise in Buffalo Harbor of 3.4 feet and a coincident rise in Erie of 1.3 feet.




94972°—Bull. 77—11. (To face page 110.) No. 1

CHART XXXVIII.




94972°—Bull. 77—11. (To face page 110.) No. 2.

CHART XXXIX.


94972°—Bull. 77—11. (To face page 110.) No. 3.

CHART XL.

Note the sharp drop of water level at Buffalo beginning 5 p. m. January 9, in spite of a wind velocity of 30 miles from the west, maintaining a surface current toward Buffalo.

The wind kept its direction and increased in velocity up to noon Monday, January 9. Its velocity decreased, but the direction of the wind remained the same up to Tuesday morning, January 10. The water level in Buffalo began to fall rapidly 5 a. m., Monday, January 9, and in 12 hours fell 3.4 feet.

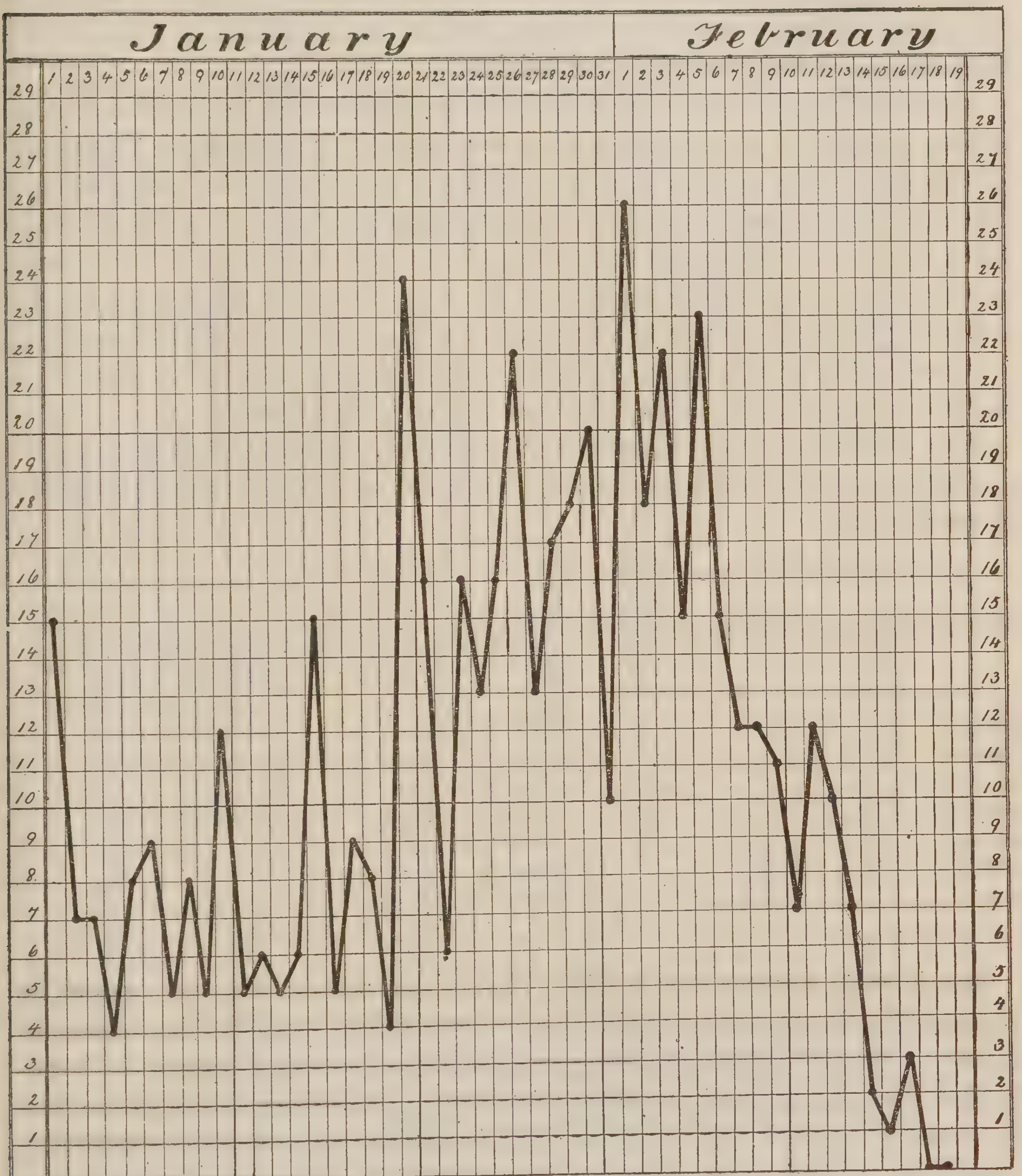



CHART XLI.—Erie, Pa., typhoid fever cases, corrected as to date of onset by Mr. F. Herbert Snow. Mr. Snow's canvass showed that the onset was from 8 to 12 days before the report was received by the board of health.

The water level began to drop in Erie at 8 p. m. Monday, and within 12 hours had fallen 1.6 feet, equal to a discharge of 256,000,000 cubic feet of polluted water from the harbor. These two occurrences of peculiar conditions of wind and current make it possible that gross pollution at the waterworks intake took place upon two occasions at least, viz, December 9, 1910, and on or about January 9, 1911.

How long after gross pollution of the intake would the effect be manifest in the records of the board of health? Questioning of hundreds of cases showed that as usual in other cities the reporting of cases to the board of health averaged 9 to 10 days after the onset of the disease. This is due to uncertainty among the physicians in exact diagnosis. There seems to be a tendency to await a positive diagnosis before reporting. Then, too, in many cases, a week or 10 days is lost before calling a physician.

As a result of his canvass Mr. Snow transferred 62 cases from January to the end of December, and moved back 101 cases from February to January. As a result, the apices of the typhoid curve, showing the probable onset, antedate the corresponding apices on the chart made from the board of health figures by from 10 to 12 days. The chart made from the corrected figures of Mr. Snow shows a sharp rise on the following days, January 1, 10, 15, 20, 26, February 1, and February 4; a corresponding rise from 8 to 12 days later is shown on the chart made from the cases as reported to the board of health.

The following table shows comparatively the dates of the corresponding apices of the two charts, and the number of days difference in each case:

| Date of rise on chart corrected as to onset by investigations of Mr. Snow. | Date of rise on chart uncorrected as to onset, made direct from board of health statistics. | Number of days difference. |
|---|---|---|
| Jan. 1 | Jan. 12 | 11 |
| Jan. 10 | Jan. 20 | 10 |
| Jan. 15 | Jan. 23 | 8 |
| Jan. 20 | Jan. 30 | 10 |
| Jan. 26 | Feb. 6 | 11 |
| Feb. 1 | Feb. 13 | 12 |
| Feb. 5 | Feb. 16 | 11 |

From these figures it is evident that a correction of 9 days would be reasonable to cover the time lost in reporting cases to the board of health. Twelve days is conceded to be an average period of incubation for water-borne typhoid infection. Allowing 12 days for the incubation period and 9 days for the period of delay in reporting, would be a total of 21 days, so that about 21 days after gross pollution of the waterworks intake an explosive outbreak might be expected.

Weather conditions made possible gross pollution of the intake on or soon after December 9, 1910, and January 9, 1911. Adding 21 days to these dates we would expect (provided gross pollution took place) to find a sudden pronounced increase in the number of cases reported to the bureau of health on or about December 30 and on or about January 30.


CHART XLII.—Erie, Pa., typhoid fever cases reported to the board of health, by days, November, 1910, to March, 1911. Note the two distinct explosive outbreaks, one beginning December 31 and the other beginning January 30.

Examination of Chart XLII reveals at a glance two distinct explosive outbreaks. The first began December 31 and ran through January, showing a tendency to subside on January 28 and 29.

The second began suddenly January 30, when the number of cases jumped from 2 on the 29th to 29 on the 30th.

Making due allowance for the time lost in reporting cases and for the period of incubation, these outbreaks seem to have been caused by gross sewage pollution taken in at the lake intake about December 9, 1910, and January 9, 1911, and in the days following these dates. No attempt is made to show that sewage pollution of the intake did not take place at any other time in December, 1910, and January, 1911, but the two periods immediately following December 9, 1910, and January 9, 1911, are pointed out as the periods when conditions for pollution were most favorable. That such pollution did occur and that it was responsible for the two outbreaks shown on the daily chart is more than probable. The time elapsed between the period when pollution probably took place and the outbreak was almost identical in both instances, about 21 days.

Most favorable conditions for sewage pollution at the intake were also in evidence on December 14–15, 1910; January 3, 1911; January 6, 1911; and February 2, 1911, as shown by the charts, and it is not unlikely that some pollution at the intake took place on these dates also.

The whole question of lake currents requires much careful study and experimental work before conclusions can be formed as to their normal and abnormal variation.

The existence of certain currents and how certain disastrous results are produced by them will be open to dispute until such work is done. In the case of Lake Erie such minute observation has not been made. Unfortunately, the time when such float observations should be made usually presents weather conditions that make the feat very difficult if not impossible. It is doubtful from the standpoint of the spread of water-borne diseases if experiments carefully made and extending over a long period of daily observation with floats, etc., are necessary. Nevertheless, they would be of great scientific interest and might be made either by United States Lake Survey or some other governmental agency. We are in possession of enough data to show that Lake Erie currents can not be relied upon, may come from almost any direction, and that absolutely no dependence can be placed in them for the protection of waterworks intakes from pollution.

It can also be shown that sudden and appalling disaster may follow occasional pollution of an intake even so "favorably placed" as that of Erie in January, 1911. It can be shown further that any and all of these "favorably placed" intakes are subject at times to sewage

pollution and that improvement of the sewerage system and filtration or treatment of the water properly carried out is necessary to protect the public against this occasional pollution.

In response to an order of the State department of health, the city engineer of Erie submitted a tentative plan for a complete system of sewers and for a disposal plant.

The city engineer's plans call for two main intercepting sewers. One of these intercepting sewers will extend along Front Street from Mill Creek the entire length of the city westerly and the other main intercepting sewer will extend up the valley of Mill Creek the entire length of the city.

The Front Street intercepter will begin at a manhole on the west bank of Mill Creek immediately south of the Pennsylvania Railroad; thence it will extend westerly a distance of about 1,000 feet across the lowlands and beyond Parade Street to the bluffs; thence it will continue along and in the slope of the bluffs between the public highway above and the railroad below to French Street; thence it will pass under the parked triangle and in Front Street to State Street, a total distance of 3,300 feet. From the beginning of the bluffs westerly for 1,400 feet to a point about midway between Holland and French Streets will be laid, in a cut to be made in the bluff averaging about 7 feet, a cover over this sewer. But this cut is not significant, because the plan of the city is to even up the rough, irregular surface of the bluff and seed it down to form a part of the Lakeside Park.

Beyond State Street the line of the sewer will be through the existing Parkway, a distance of 700 feet, to the Canal Street sewer. Here the 30-inch structure will terminate. The grade here is 10 feet higher than the grade of the canal sewer, necessitating the relaying of the canal sewer up the gulley about 600 feet. The plan is to make a 20-inch pipe connection between the two sewers and to collect the dry-weather flow of the canal sewer and a percentage of the storm water from the canal sewer and deliver it into the intercepter. The surplus storm water will pass down the existing sewer and be discharged into the harbor as at present.

On the line of the 30-inch sewer manhole connections are provided for every existing public sewer now emptying into the harbor, but only the dry-weather flow will be intercepted and a part of the storm water flow. Details of these connections and the percentage of storm water to be admitted have been worked out for at least three types of regulators, and the city engineer is now experimenting with each to determine the most practicable arrangement for the different sewers to be intercepted. The existing outlets will be maintained to discharge into the harbor the surplus storm water and mingled sewage not admitted to the intercepter. There will be some changes in the grades of every street-sewer intercepter; however, since the grades of

these streets ascend rapidly to the city, no difficulty in adjusting the grades obtained, and the cost is comparatively small.

Westerly from the canal sewer the main intercepter will extend for a distance of 4,300 feet to Little Cascade Creek. In this entire distance the sewer line will be built in the slope of the bluff. Eventually this slope is to be evened up and made a part of the city park system. The structure will be in excavation until the creek is reached, where an embankment and culvert to support the sewer and a public road is to be built across the creek. One thousand feet up the valley is the present outlet of the Little Cascade sewer culvert.

It is proposed to extend this culvert by a 4-foot sewer down the ravine at a higher grade, terminating the culvert at the intercepting sewer. The surplus storm water will overflow and pass down the natural channel to the harbor from the intersecting sewer. The ravine will be eventually filled in over the new culvert.

From Little Cascade Run westerly the intercepter will terminate at Cranberry Street, the city line, 11,600 feet from the point beginning at Mill Creek. Here it will connect with the Cranberry Street or Cascade Creek sewer outlet, where there will be an intercepting and regulating chamber and where the surplus storm water will go to the creek.

The flow of sewage in all of the sewers mentioned, discharging into the harbor west of Mill Creek and designed to be intercepted by the proposed Front Street sewer, as measured by the city engineer during the protracted drought of the season of 1908, aggregated 2,825,000 gallons per 24 hours, of which 1,300,000 gallons came from the populous district served by the Little Cascade sewer outlet. Next in importance was the discharge from the canal sewer, whose flow was at the rate of 835,000 gallons per 24 hours.

It is estimated that ultimately 12,000,000 gallons of dry weather flow of sewage may be delivered to the 30-inch intercepter.

The Mill Creek intercepter will begin at the manhole near the railroad, where the Front Street intercepter begins; thence it will extend upstream along and in a retaining wall proposed to be erected on the west bank of the creek 1,000 feet to Third Street; thence it will extend in Third and Parade Streets, intercepting a sewer in the former and providing a new sewer for the latter to Fourth Street; thence it will be built in a concrete retaining wall along the west bank of the creek to Fifth Street, a total distance of 2,300 feet from the starting point. This section of the sewer is to be circular and 36 inches in diameter.

The details of each connection with an existing sewer outlet into Mill Creek have been carefully worked out. Minor changes will have to be made in every connection. Without an exception, not hereinafter mentioned, the new connections to the intercepting sewer will be provided with waste weirs to discharge surplus storm water into the creek through the existing outlet. This is the only use to which

the old outlets will be put. At Second Street, east, is to be built an inverted siphon. At Fourth Street, east, and Parade Street, south, the sewer connection will be carried across the creek on the arch of the bridge to the intercepter.

At Fifth Street, east, a 12-inch cast-iron pipe will be carried through the walls of the bridge above the flood line of the creek to a drop manhole connecting to the intercepter. No overflow is provided here.

From Fifth Street the intercepting sewer will continue upstream in a proposed concrete retaining wall, passing around the abutments of the bridges at Sixth and Seventh Streets to a point 3,635 feet from the beginning, where the sewer will pass under the bed of the channel and take a course across private property along Eighth Street to Holland Street and thence south in Holland Street to Tenth Street and in Tenth Street to Mill Creek, where the 36-inch intercepter terminates, this point being 5,000 feet distant from the manhole at Front Street.

From the end of the 36-inch sewer in Tenth Street a 24-inch intercepter will be extended under the creek and westerly in Tenth Street to and along French Street southerly to Twenty-sixth Street, 11,000 feet from the point of beginning at Front Street. The average depth of this sewer line to the top of the pipe is in excess of 10 feet, the minimum grade on the 24-inch sewer being 1 foot in 200 and the grades on the smaller sizes being considerably in excess of this.

At the present time there is no sewer in French Street beyond Eleventh Street, and the intercepter will take the place of a street sewer, and at the same time it will collect the flow from all of the existing sewers now going into the creek.

The total flow of all the existing sewer outlets into Mill Creek, as measured by the city engineer during the protracted drought of last season, was 8,100,000 gallons per 24 hours. Quite a proportion of this flow is leakage from the ground, which can not be prevented.

The city engineer estimates that ultimately there may be 12,000,000 gallons daily flow of house sewage from the Mill Creek drainage district, and that an equal amount of storm water—the first flush of showers carrying with it the deposits in sewers—should be provided for in the intercepter, and with this as a basis the size and grade of the intercepter has beeen designed.

The design of the intercepting sewer system is not to prevent absolutely the discharge of sewage into the harbor, but to reduce this discharge, which is now continuous, to short periods of a few hours at a few times only during the year. This improvement is not beyond the financial ability of the city to accomplish in the near future. To effect a greater improvement than this would involve the reconstruction of most of the sewers of the city or the paralleling of them by storm drains.

There are about 50 miles of paved streets in Erie. The expense of an absolute separation of the sewage from the storm water would be so much greater than the cost of the plan proposed that the additional safety to public health secured by this excessive cost, in the opinion of the local authorities, would not be commensurate. The city's experts maintain that the sanitary condition effected by the proposed plan will amount practically to the entire removal of the menace to public health now existing in the harbor by reason of the discharge of sewage therein, and that for all future time these plans will prevent any material pollution of the waters of the State and safeguard the public health to a reasonable degree.

The sewers east of Mill Creek discharging into Lake Erie are, according to the city's plan, to be intercepted and the flow collected at one point at the mouth of Lighthouse Run, where a receiving well and pumping plant will be installed to raise the sewage into the manhole at the junction of the Front Street and Mill Creek intercepter. The surveys and details of this interception have not been completed.

The sewage of the soldiers and sailors' home can be delivered by gravity into the Mill Creek intercepter.

The plan for sewage disposal provides for the conveying of the sewage from the junction of the two intercepters on the west bank of the creek, as described in the permit, through a conduit of the required size, which will be carried at grade over Mill Creek with reenforced-concrete construction, and under the Philadelphia & Erie Railroad tracks, to suitable basins just north of the railroad, where the sewage will be well clarified by screening and sedimentation. The sewage will be treated in plain settling basins and the sludge will be septicized in separate compartments in such a manner as to prevent objectionable odors. The clarified sewage will be run into the open lake through a submerged sewer to a distance of from 6,000 to 8,000 feet from the harbor inlet, to a depth of 20 feet to 30 feet of water, from 4,000 to 5,000 feet from shore, and well dispersed through numerous orificies in the sewer at or near the lake bottom. This method of sewage disposal has been adopted on the recommendation of Messrs. Hering & Fuller, consulting engineers, of New York City, and is in principle an Emscher tank system as perfected by Dr. Carl Imhoff in Germany.

The proposed site for the plant is a piece of land bordering on Presque Isle Bay in the northern part of the city, located on the north side of the Philadelphia & Erie Railroad tracks and between Mill Creek and the soldiers and sailors' home grounds.

The clarified effluent from the upper basin flows into a well from which a 54-inch diameter pipe extends in a northeasterly direction through the soldiers and sailors' home grounds, 2,500 feet; thence

into the lake 5,500 feet into water 26 feet in depth, where the pipe branches into two dispersion pipes each 40 inches in diameter at the branch and 26 inches at the outer end. One of these arms extends north 80 feet and has 53 dispersion orifices 5 inches in diameter in the upper quarter, and the other arm extends east 60 feet with 40 dispersion orifices.

Sludge drying beds are provided for with an area of 10,400 square feet and a depth of 1 foot. The beds are underdrained with lines of 3-inch land tile placed 6 feet between centers and covered with coarse cinders. The sludge is drawn from the wells below the settling basins through a 12-inch iron pipe extending from the bottom of each well to and through the outside wall at a point 5.5 feet below the surface of the sewage in the basin, thus giving a sufficient head to drive the sludge up through the pipe, from which it flows into a trough leading to the drying beds.

The plans of the city of Erie for improvement extension of its sewer system and for sewage disposal were approved conditionally by Dr. Dixon, commissioner of health.

The following are the conditions imposed:

First. The city shall proceed during the season of 1911 to construct and put into operation the Front Street intercepter in conformity with the plans approved.

Second. The city shall during the season of 1911 institute and conduct a series of experiments with the type of sedimentation and digesting sludge tanks and final method of disposing of the sludge and at the close of the year submit a detailed report of the tests with any modifications they may suggest in the plans now offered for consideration to the commissioner of health for approval.

Third. The plans to be finally considered shall provide for the disposal of all of the sewage of the city at one point in the lake after such treatment as shall be decided upon. There shall be no by-pass or discharge of raw or treated sewage at any place except this one place, and according to the method to be finally agreed upon.

The radical improvement in sewage disposal at Erie exacted by the State department of health may be expected in itself to have a marked effect upon the public water supply. In addition to this, however, the commissioner of health intends to exact of the Erie commissioners of waterworks a safe potable water for every day in the year, and in his opinion this type of water consistently clear and safe can be furnished only by filtering the present supply. In his opinion also, treatment with hypochlorite might suffice to render pathogenic organisms harmless, but the turbidity which is common in certain seasons of the year would be unimproved.

Sedimentation as originally proposed by the water commissioner on Presque Isle might have done much to get rid of the turbidity,

and perhaps if the storage capacity had been greater and the basins properly lined some improvement in the water from the bacterial standpoint would have been effected. However, the sedimentation basins were never much more than holes in the ground, and in such condition made the water apparently worse, and their use was discontinued after a very short trial.

The State department of health will in all probability require that the filtration be effected on the mainland after the last opportunity for pollution through a leaky pipe has been passed. There is a site available in the vicinity of the pumping station with ample room for a rapid sand filtration plant.

## CONCLUSIONS.

1. An excessive typhoid fever rate has prevailed in Erie for many years. In 10 out of the past 11 years this excess has been due to unusually high rates in winter and spring.

2. The entire sewage of Erie goes into Erie Harbor and Lake Erie.

3. Up to 1908 the public water supply was taken from the grossly polluted Erie Harbor direct and delivered untreated and unfiltered to the consumers. Since September, 1908, the water supply has been drawn from Lake Erie 5,000 feet north of Presque Isle. This intake was subject to occasional pollution, depending upon certain combinations of weather conditions.

4. The pollution of Lake Erie by sewage outside of the city of Erie on the Pennsylvania shore of the lake is at present a negligible quantity.

5. The permit to discharge sewage granted by the State commissioner of health to the Erie Improvement Co. has several important provisions. These indicate that the State intends to exercise its supervisory power over the proposed new city, insuring that raw sewage will be discharged into Lake Erie from this source only temporarily, and that adequate sewage treatment will be demanded when the city actually comes into existence.

6. Conditions necessary to produce sewage pollution of the Erie intake are a lake current from east to west around Presque Isle and a rapid lowering of level in Erie Harbor, producing rapid discharge of a large quantity of sewage-polluted water from the harbor into the lake current.

These conditions are produced by winds from various directions, but the conditions necessary for pollution are produced in the most dangerous degree by continued winds from the southwest quadrant.

From a careful study of data giving stage of water, direction of wind, and velocity of wind hourly for each day during December, 1910, and January, 1911, it is evident that the most favorable conditions for pollution of the Erie waterworks intake existed on December 9, 1910, and on January 9, 1911.

Corroborative evidence that such pollution of the water supply through the lake intake actually took place is furnished by the explosive outbreak that occurred, in each instance about 21 days after the beginning of the period of probable pollution.

7. Pollution of Erie Harbor and other portions of Erie's water front by the sewage of the city of Erie, coupled with failure to filter or treat the public water supply, have been responsible for outbreaks of typhoid fever in the winter and spring months in Erie, including the epidemic of January and February, 1911.

8. Dependence upon Lake Erie currents to carry sewage-polluted water away from the waterworks intake at Erie gave a sense of false security which made possible the disaster of January and February, 1911. The placing of an intake in Lake Erie as great a distance as 5 miles from the nearest source of pollution, and to the westward thereof, only affords protection to the intake part of the time. In other words, such an intake is exposed to occasional pollution of a serious character.

9. Lake Erie currents are very unstable and irregular and no dependence can be placed upon them for protection of an intake from sewage-polluted water.

10. During the period from January 1, 1900, to February 28, 1911, there were over 3,200 cases of typhoid fever in Erie and 320 deaths. Allowing an average typhoid death rate of 20 per 100,000 population, Erie should not have had more than 150 deaths and 1,500 cases, so that at a conservative estimate there were at least 170 deaths and 1,700 cases of typhoid fever which were preventable, should never have occurred, and which were in all probability due to polluted water.

11. An outbreak of an acute diarrheal disease locally called winter cholera occurred about December 10, 1910. It was very widespread, attacking thousands, although, as a rule, not fatal in result. A similar disease has occurred before, and it seems to precede by two or three weeks severe typhoid outbreaks, and is generally supposed to be due to sewage pollution of the public water supply.

12. Deaths from diarrhea and enteritis in Erie are not in excess, and child mortality is but slightly higher in Erie than the average for Pennsylvania. Upon investigation this was found to be due in 1909 to an excess of deaths from measles and whooping cough and was unconnected with the character of the water supply.

13. If the proposed plan for treating the sewage of Erie as outlined above is carried into successful operation there will be a vast improvement over existing conditions and the menace from Erie's sewage will be greatly reduced.

14. The installation of a hypochlorite plant in Erie this year is a valuable temporary protection against typhoid, but a more perma-

nent system of filtration will be exacted in the near future, rapid-sand filtration with a coagulant probably being used, which will add to the advantage of a safe water, the quality being clear every day in the year.

The commissioner of health will require also that the filtration be effected on the mainland near the present pumping station. This is necessary to guard against possible leakage either now present or in the future, due to imperfections or injury of the steel pipe submerged below the sewage-polluted waters of the harbor.

15. In view of the commercial and industrial importance of Erie, and because of the enormous traffic carried on in the harbor, excessive prevalence of typhoid fever and a contaminated water supply constitute a serious menace to the public health. Not only are employees engaged in interstate traffic exposed to this menace, but persons from other States traveling to or through Erie are similarly exposed. Any of these persons becoming infected in Erie may travel to their homes during the incubation period or to lake ports in other States and there fall ill and be responsible for secondary cases.

## THE OHIO SHORE OF LAKE ERIE.

### CONNEAUT.

Conneaut is a city of about 10,000 inhabitants, situated upon Lake Erie, at the mouth of Conneaut River. It owes its importance as a port to the iron and coal industry. It has large railroad shops and a few minor industries.

It is fairly well sewered and has sewers of the separate type. There is a large foreign population (Scandinavians, Slavs, and Italians), but sanitary conditions are better than usually found in towns with a large foreign element.

In 1890 a water company contracted to furnish water to the city. This water was taken from Lake Erie, at first from driven wells on the beach, later from "Cook" wells, which are metal perforated pipes forced obliquely under the sandy lake bottom, and finally direct from the lake by means of an emergency inlet, which was at first seldom used.

An epidemic of typhoid fever in 1899 was investigated personally by the secretary of the State board of health, Dr. C. O. Probst. The sewer outfalls for the city discharge into the Conneaut River, and the outlet of this river between piers is a comparatively short distance east of the emergency intake.

Dr. Probst's conclusions were as follows:

The evidence here presented shows that in all probability the public water supply of Conneaut was largely responsible for their epidemic of typhoid fever. It may be briefly summed up as follows:

1. Eighty-four, or 89 per cent, of the cases reported since the outbreak used hydrant water.

2. The west end of the village, where wells are used almost exclusively, escaped the disease.

3. Colon bacilli, indicating sewage contamination, were found in the hydrant water when water was being pumped from the lake.

4. The fact that the conditions are such that the lake water at the intake can not escape pollution at times.

5. The coincidence in the time of the prevalence of typhoid fever and of the time of the use of lake water.

As a result of Dr. Probst's inspection and report, plans for a filtration plant were submitted and approved by the State board of health.

The filtration plant was installed in 1900, and consisted of two Jewell mechanical filters—using sulphate of aluminum as a coagulant. The water was taken from Lake Erie at a point 1.500 feet west of the mouth of the river and 844 feet from the shore line, in 14 feet of water. The mere placing of the intake to the westward of the sewage-laden river is a very insecure protection, resorted to by lake towns depending upon an easterly current to carry pollution away from the intake.

For a considerable number of days each year this does not take place and the polluted water enters the intake, necessitating good filter efficiency to prevent epidemics.

In April, 1901, an official of the State board of health investigated another outbreak of typhoid in Conneaut and found that the waterworks plant had been without alum for several days (March 18, 19, and 20), and no coagulant was used during those days at least.

Again, in April, 1902, an epidemic was investigated in Conneaut and found to be due to inefficiency of the filters. Sufficient coagulant was not used and the filters were worked beyond their capacity. This trouble was in evidence again in 1903–4.

An epidemic from November, 1906, to April, 1907, in Conneaut was exhaustively studied by engineers sent by the State board of health. Faulty features in the mechanical filters and in their manipulation was shown to be responsible. The conclusions of the State engineering experts were as follows:

1. The data point most conclusively to the public water supply as the source of infection in nearly all of the cases of typhoid fever dealt with in the recent investigation.

2. Owing to the several faulty features in the construction of the filtration plant, previously described, it is at times impossible to afford complete protection to consumers, even with the most careful attention on the part of the filter attendants.

3. As a reasonable safeguard against future epidemics of typhoid, and also to promote economy in waterworks maintenance, the following alterations in and additions to the waterworks plant should be made at once.

(*a*) A coagulation tank, of 125,000 gallons capacity, should be provided.

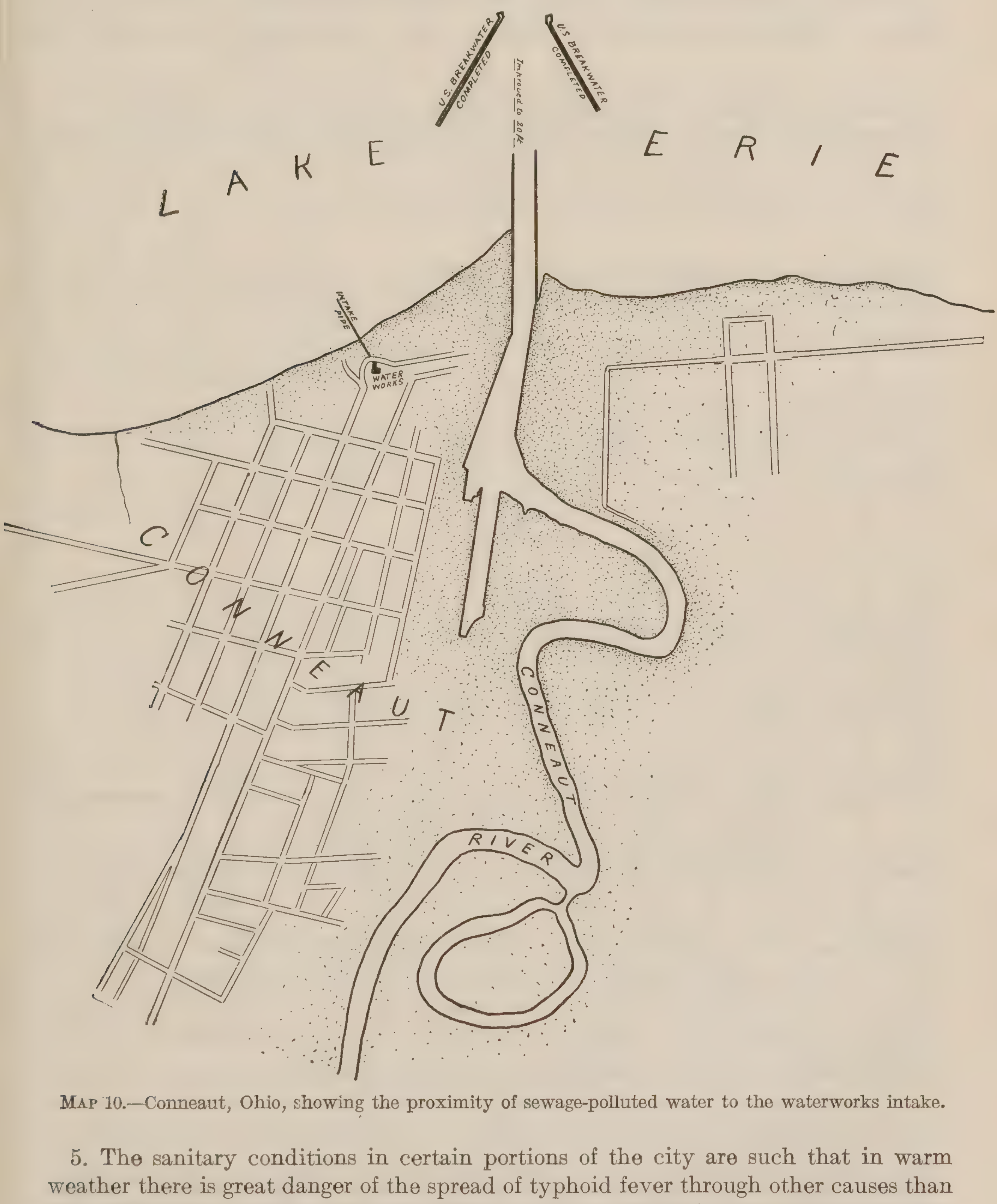
(*b*) A new filter unit should be added..

(*c*) Each filter should be provided with a suitable rate-controller.

(*d*) The open wash water drain and the filtered water flume should be replaced with iron pipes.

(*e*) The clear-water basin should be enlarged so as to provide at least one hour's storage capacity.

4. Conditions would be greatly improved by purifying the sewage of the city before discharging same into Conneaut Creek, but the purification of the sewage would not render unnecessary the reconstruction and proper operation of the filtration plant, since there would remain considerable danger from pollution by surface washings, discharges from vessels, and from various other sources.




MAP 10.—Conneaut, Ohio, showing the proximity of sewage-polluted water to the waterworks intake.

5. The sanitary conditions in certain portions of the city are such that in warm weather there is great danger of the spread of typhoid fever through other causes than the public water supply. These conditions may be greatly improved by (*a*) requiring all houses to connect with the public sewers wherever sewers are available; (*b*) prohibiting the discharge of sink drainage into ditches or over the surface of the ground; (*c*) prohibiting the use of privies belonging to houses having sewer connections; and

(*d*) causing privies belonging to houses having no connection with sewers to be built as to be readily accessible for cleaning and inspection, but encased in such a manner that no fecal matter is exposed or likely to be washed away.

The filter plant at Conneaut was improved to some extent as a result of the recommendations of the State authorities. Two coagulation tanks of 79,000 gallons capacity each were provided. There are now 6 filter units, each having a daily capacity of 500,000 gallons. There is no rate controller. It is proposed to increase the

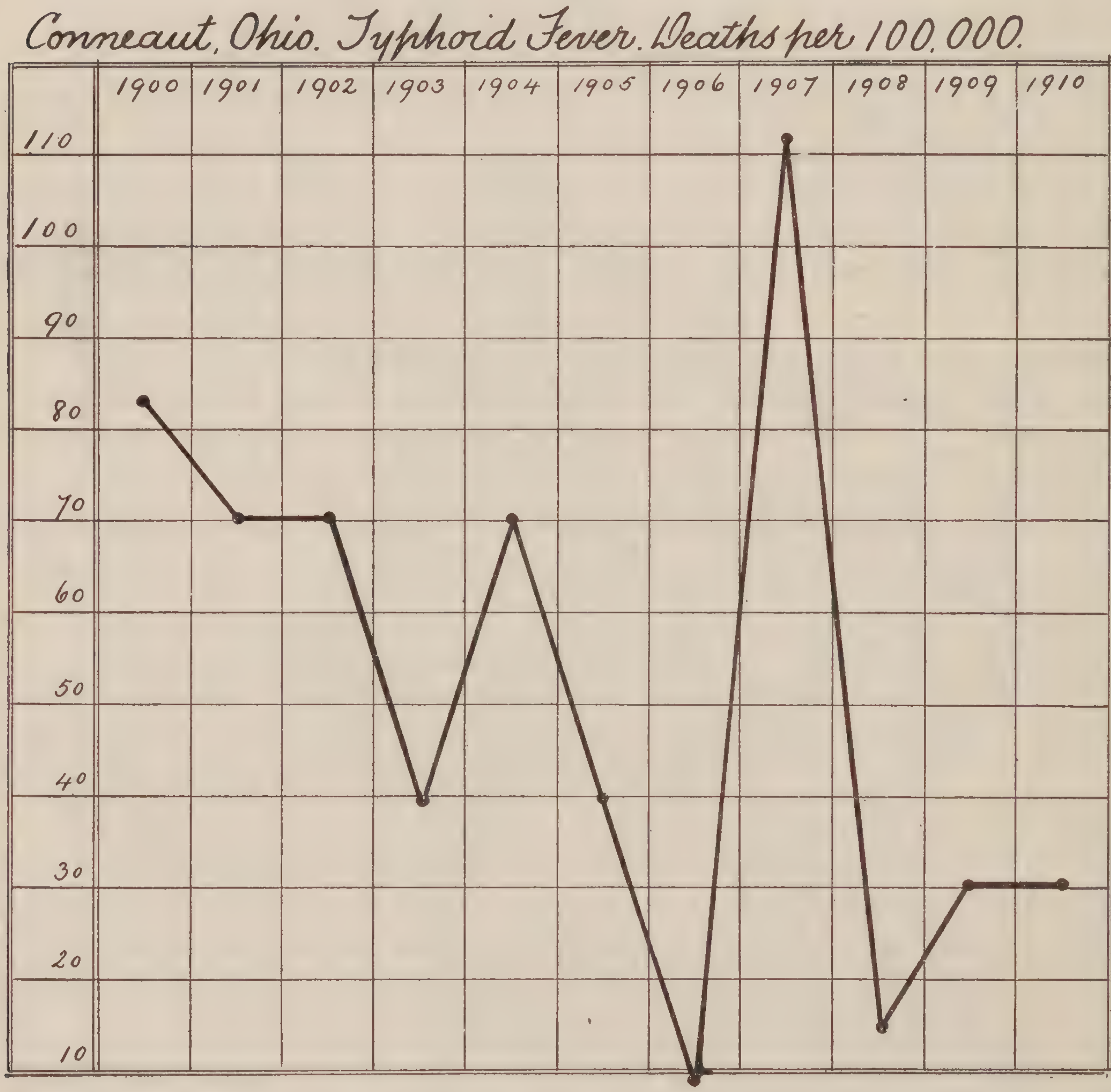



CHART XLIII.—Conneaut, Ohio, typhoid fever: Deaths per 100,000, 1900–1910.

storage capacity for filtered water by the end of June, 1911, to 56,000 gallons, which is about one hour's supply.

Typhoid conditions have improved in Conneaut since correcting some of the faults of the filter plant. In 1909 there was 1 death in July and 2 in August. In 1910 there was 1 death in January and 2 in October. This year (1911) 3 deaths in January suggests that something may have gone wrong at the plant as in the past.

The experience of Conneaut in the matter of typhoid fever illustrates two points, viz, the instability of currents in Lake Erie and

the necessity of State supervision of municipal filter plants. The danger of depending upon lake currents to consistently carry sewage in one direction, that is, away from the intake, is apparent. The greatest danger from the polluted river water exists naturally in time of high water or flood. At this time in spite of the greater volume of water theoretically available for dilution little or no opportunity for sedimentation is allowed because of the increased velocity of the stream, and we have stratification rather than dilution of the polluted river water.

The velocity is such that contaminated water is quickly carried to the intake, provided the necessary variation from the normal in wind and current is present, and it has been noted that it is precisely at these times of flood that this variation of wind and current most frequently occurs.

Close supervision of filter plants and frequent water examinations are essential to compel constant efficiency of the filters. Disaster in Conneaut followed failure to use enough coagulant, and also forcing the filter beyond its capacity.

It is not sufficient to have an installation capable of doing the work. The State authorities must assure themselves that the filter is being properly operated and that a good, safe water is being constantly furnished.

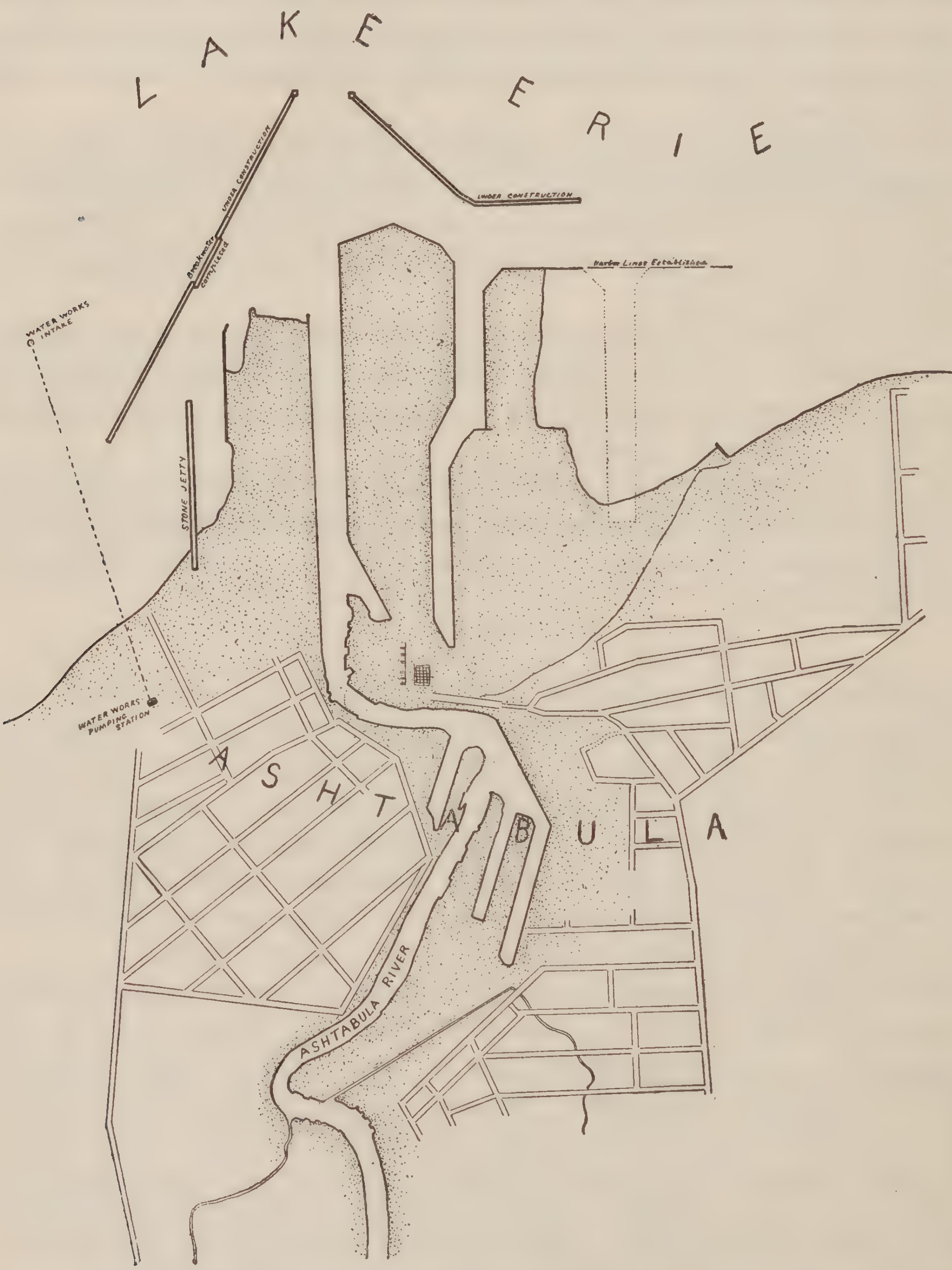
## ASHTABULA.

Ashtabula has a population of about 17,000. It consists of two distinct portions. The business section is inland about 2 miles, and the harbor section is situated on the lake at the mouth of the Ashtabula River. Ashtabula proper, the inland section, is fairly clean and well kept. In the harbor section, however, sanitary conditions are not of the best. The city is divided into three sewer districts, the entire flow of sewage discharging into the Ashtabula River, one outfall at the foot of Bridge Street and two at Mary Street.

District No. 1 comprises most of Ashtabula proper and the southwestern portion of the corporation. There are about 7,500 people tributary to the sewers, which are of the separate type. District No. 2 comprises Ashtabula Harbor and has about 3,000 persons dependent upon the sewers, which are of the combined type. District No. 3 takes in the southeasterly portion of the corporation, has separate systems of sewers, and its outfall is combined with that of District No. 1, discharging into the river at Mary Street.

In 1908 the State board of health approved the extension and enlargement of District No. 3 of Ashtabula upon condition that the city within three years present plans for approval providing for the purification of the sewage of the entire city, and that approved plans be carried out and sewage purification works placed in satisfactory operation within five years from March 9, 1908.

The water supply of Ashtabula is taken from Lake Erie. The intake crib is 2,600 feet from the shore line in 26 feet of water. The water flows by gravity through a 24-inch pipe to a pump well 30 feet in diameter and 15 feet deep. It is pumped from this well to a reservoir for low and a standpipe for high pressure services.




MAP 11.—Ashtabula, Ohio, showing proximity of the waterworks intake to the sewage-polluted harbor.

The reservoir is 216 feet above the pumps and the standpipe 100 feet higher. The reservoir is lined with brick and has a capacity of 2,225,000 gallons. The standpipe is 100 feet high, 20 feet in diameter, and holds 225,000 gallons. The holding capacity of resevoir and standpipe is not sufficient to obtain any noticeable degree of purifi-

cation by storage, and tap water has approximately the qualities of lake water.

The Ashtabula River, carrying the sewage of Ashtabula, discharges into Lake Erie about 3,500 feet from the waterworks intake crib. The river is carried out into the lake between piers a distance of 1,000 feet beyond its natural mouth. The intake is placed to the westward of the mouth of the river, as is usual in cities upon Lake Erie, depending upon the normal lake current to the eastward to protect the intake from the sewage polluted waters of the river. Under ordinary conditions the amount of sewage entering the lake is relatively small and the stream flow sluggish, and the normal lake current would carry this pollution away from the intake. Under storm conditions, and especially when the river is in flood, the prevailing winds and currents may and frequently do change and the water of the sewage-polluted Ashtabula River may then reach the intake. Realizing this danger the State Board of Health of Ohio as far back as 1901 called attention to it in the following words,[1] which viewed in the light of succeeding events were strikingly prophetic:

> At Ashtabula there seems to be in general but little pollution at the intake, still it is only a question of time or direction of currents until serious pollution will take place if raw water from the present intake continues to be used and the city sewage emptied into the river.

High typhoid rates prevailed in 1901, 1902, and 1903, but in 1904 the explosion following serious pollution at the intake as predicted by the State board of health in 1901 really occurred. This epidemic was carefully studied by the bacteriologist and chemist of the State board of health and the following conclusions close the report:

> The investigation indicates that this epidemic of typhoid was due to the use of an unpurified and polluted public water supply.
>
> The water supply was polluted from the sewage of Ashtabula almost if not quite continuously from the middle of January until as late as the middle of April, and possibly longer.
>
> The number of cases increased in due time after high waters caused the sewage laden waters of the lower portion of the river to go out under the ice.
>
> The present conditions of water supply and sewerage at Ashtabula are such as to stand a menace to the health of the city, although under favoring circumstances of nature the water may be usable more or less of the time.
>
> At a meeting of the State board of health held June 22, 1904, this matter was discussed and it was decided to send a communication to the city council and to the board of health of Ashtabula, urging the installation of a water purification plant at the earliest possible time, as a means of preventing epidemic outbreaks of typhoid fever.

A filter plant was finally installed in March, 1909, nearly five years after the strong recommendation of the State board of health was made.

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[1] Report State board of health, 1901, p. 408.

It is a mechanical or rapid-sand filtration system, using alum as a coagulant, about 2 grains per gallon, the amount varied according to turbidity of the raw water. It consists of 6 units of 1,000,000 gallons capacity each.


CHART XLIV.

*Typhoid deaths in Ashtabula, 1909 and 1910, by months.*

| Months. | 1909 | 1910 | Months. | 1909 | 1910 |
|---|---|---|---|---|---|
| January | 0 | 0 | August | 1 | 0 |
| February | 0 | 0 | September | 2 | 2 |
| March | 0 | 0 | October | 0 | 0 |
| April | 0 | 1 | November | 3 | 1 |
| May | 1 | 1 | December | 0 | 0 |
| June | 0 | 2 | | | |
| July | 0 | 0 | Total | 7 | 7 |

The effect of the installation of the filter plant at Ashtabula has been noticeable, but the rate still continues high. In 1909 and 1910 it was still above 40 per 100,000. Analyses of these deaths by months show that no deaths occurred in December, January, February or March; that 11 out of the 14 in the two years occurred between June and November, which argues against water-borne infection.

## PAINESVILLE, FAIRPORT, AND RICHMOND.

Painesville, Fairport, and Richmond form in reality one city. Painesville corresponds to the business and residence section of other lake towns, and Fairport and Richmond to the harbor portions. Painesville has a population of about 6,000; Fairport, 2,500, and Richmond, 500; about 9,000 combined.

Painesville has a little general manufacturing, but is supported largely by the harbor industries. It is connected with Cleveland by electric railroad, and has the appearance of a suburban town.

Fairport and Richmond are dirty towns, with a floating foreign population dependent upon the work about the elevators and docks.

Painesville has over 10 miles of sanitary sewers, and about half the population have access to them. Fairport has three distinct systems; two are of the sanitary type and one of the combined type. The entire sewage of these towns is discharged into the Grand River, the Fairport outfalls being near the mouth of the river. Approval of plans for these sewers was granted by the State board of health on condition that a purification plant would be installed when necessary.

### WATER SUPPLY.

The water supply of Painesville was installed in 1882 by a private company and has cost more than a quarter of million dollars. In 1897 the city of Painesville bought the plant for $150,000. The first supply was from wells and springs. In 1891 these were abandoned for a system of filter galleries. These are located about 1 mile southwest of the mouth of Grand River, in the sandy shore of Lake Erie. The galleries consist of plank boxes 14 inches high, 20 inches wide, and 8 feet long, placed end to end in long rows. The sides of the boxes are open, with a wire screen to keep out sand and gravel. Around the boxes is a layer of gravel, coal, and charcoal about 2 feet thick. Over this the lake sand is allowed to drift and wash. The galleries must be placed just under the edge of the water, so that wave action may keep the sand washed clean. New galleries must be built from time to time because of the recession of the water line, as the beach is building constantly. The water from the galleries enters a raceway or reservoir and is then pumped through the mains to a standpipe. The standpipe is 25 feet in diameter and 75 feet

high, with a capacity of 275,000 gallons. The top of the standpipe is 235 feet above the lake, giving a pressure in Painesville of about 40 pounds.

Ninety per cent of the people in the three towns have access to the water. Coal and charcoal are not always used, and the galleries are sometimes covered with gravel and lake sand only. The ice in winter interferes with and clogs the galleries, and the receding water line diminishes also the yield of the galleries, so that at times the supply is insufficient.

When not interfered with by ice and when working properly these filter boxes furnish a very good and safe water, but at times it has been necessary to pump water direct from the lake and disastrous results have followed the use of the emergency intake.

Out of 37 deaths from typhoid fever reported in Painesville since 1901, only 7 occurred in August, September, October, and November, while 16 occurred in January, February, March, and April. The totals are too small to draw positive conclusions, but are very suggestive of water-borne typhoid.

*Deaths from typhoid fever at Painesville, Ohio, 1901–1910, by months.*

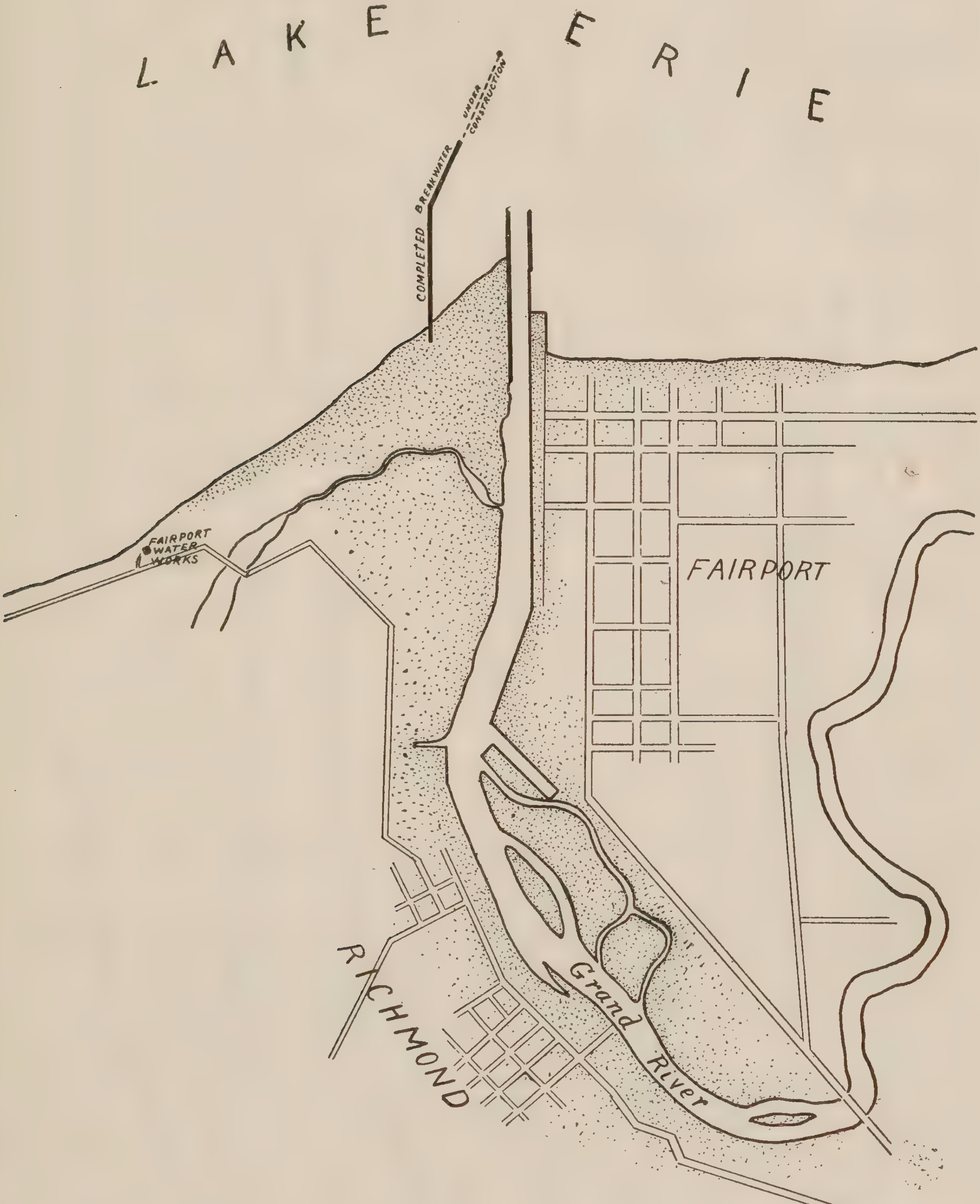
| Months. | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | Total. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| January | 2 | 1 | | | | 1 | | | | | 4 |
| February | | | | | | | 2 | 1 | | | 3 |
| March | | | | | | | | | | 1 | 1 |
| April | | 1 | 1 | | | 1 | 5 | | | | 8 |
| May | | | | | | 1 | | | | | 1 |
| June | | | | 2 | | | 1 | 1 | 1 | | 5 |
| July | | | | | | | 1 | | | | 1 |
| August | | | | | 1 | | 1 | | | | 2 |
| September | | 1 | | 1 | | | | | | | 2 |
| October | | 1 | | | | | | | | 1 | 2 |
| November | 2 | | | | 1 | | | | | 1 | 4 |
| December | | | | | | | | | 2 | 2 | 4 |
| Total | 4 | 4 | 1 | 3 | 2 | 3 | 10 | 2 | 3 | 5 | 37 |

The curve shows too high a typhoid rate for years in Painesville. During 1909 and 1910 the rate again increased from 30 in 1908 to 60 and 100, respectively. The water officials have experienced great interference from ice in cold weather, and admit the use of the emergency intake under such circumstances.

## CLEVELAND, OHIO.

Cleveland, the largest city in the State of Ohio, has a population of 560,663, according to the United States Census, 1910. It covers an area of about 45 square miles.

It is situated upon Lake Erie, at the mouth of the Cuyahoga River. The city occupies land on both sides of the Cuyahoga, which affords natural drainage for both sides to the lake.




Map 12.—Fairport Ohio, showing position of Fairport (Painesville) waterworks system of "natural" sand filtration on the beach west of Fairport.

The site of the city is for the most part sandy, resting upon shale 5 to 20 feet below. A portion of the site is clay. The tract upon which Cleveland is built has an elevation at its southern part of 250 feet, sloping gradually toward the lake and terminating in a bluff on the lake margin about 60 feet above the lake.

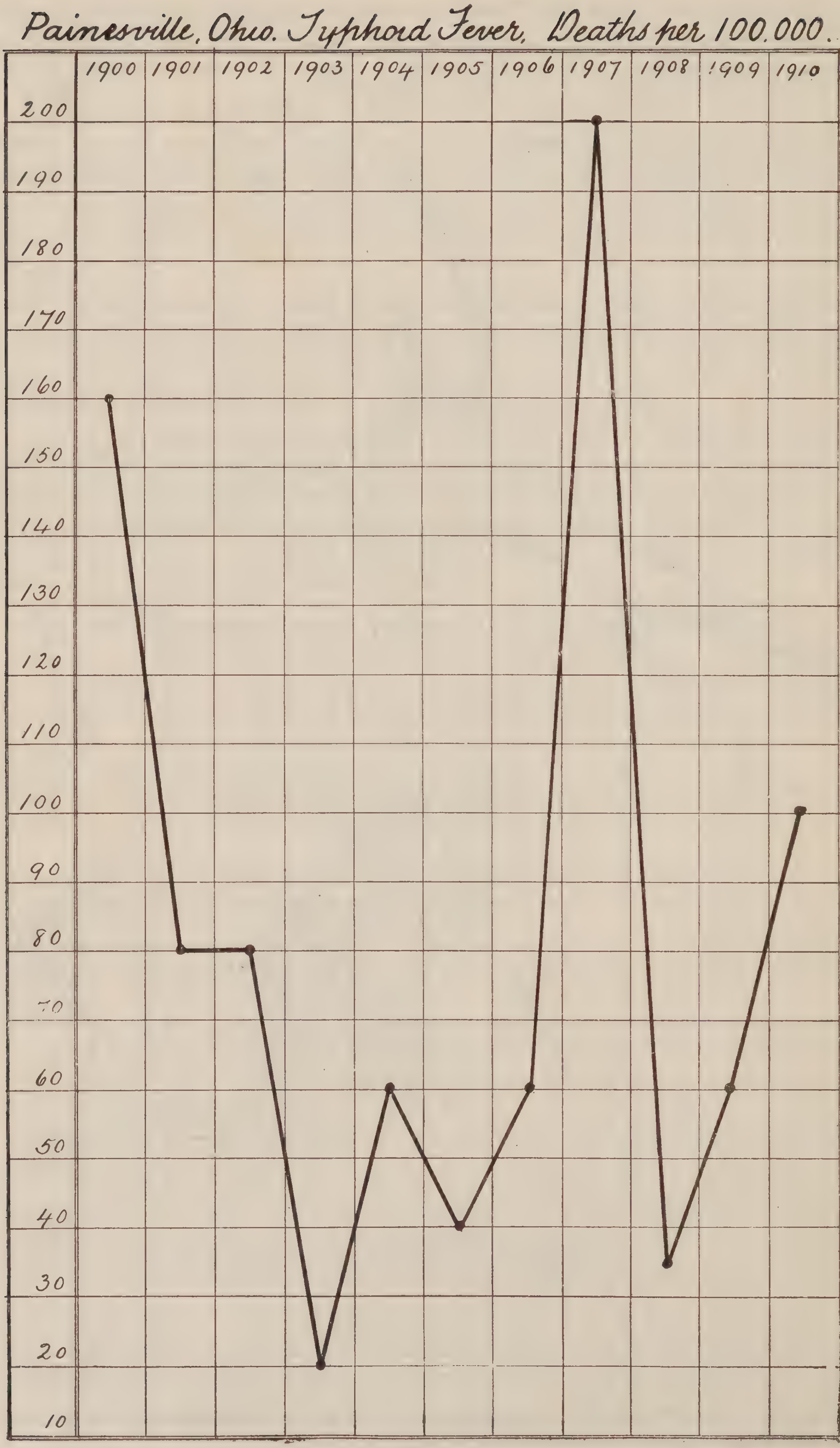

Painesville, Ohio. Typhoid Fever, Deaths per 100.000.
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

CHART XLV.


Map 13.—Cleveland, Ohio, showing position of waterworks intakes and tunnels, existing sewer outlets, existing and proposed intercepting sewers, and other data. The crosses on the map indicate typhoid fever cases occurring in the first eight days of the March-April, 1910, epidemic, showing the general even distribution of the first cases.

MAP OF CLEVELAND, OHIO, SHOWING INTERCEPTING SEWER, SANITARY DRAINAGE DISTRICTS, STORM-WATER AND SANITARY SEWER OUTLETS.

*Explanatory.*—Outlets A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P discharge only storm water. Outlets 1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 discharge both storm water and sanitary sewage. Heavy black line indicates portion of intercepting sewer now built. Broken black double lines indicate projected portions of the intercepting sewer. Sanitary sewage in district marked 1 is now discharged into outlet No. 2. Sanitary sewage in district marked 2 is now discharged into outlet No. 1. Sanitary sewage in districts marked 3, 4, 5, and 6 is now discharged into Cuyahoga River. Shaded district marked 4 is low-level district, from which sanitary sewage will have to be pumped into the intercepting sewer.

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The Cuyahoga River is about 85 miles long, drains a populous watershed of about 800 square miles, and at its mouth serves as a part of Cleveland's harbor.

Cleveland, the metropolis of Ohio, owes its premier position to its capacity for bringing into conjunction two great industrial foundation stones, iron and coal.

Eighty per cent of the great fleet engaged in the iron ore and coal carrying trade on the Great Lakes is operated from that city.

Steamship lines connect Cleveland with every port on the Great Lakes. A network of interurban electric railroads has Cleveland for a center, and supplements the railroads in bringing thousands of people daily to Cleveland.

Cleveland's steam railroad facilities include the Pennsylvania, Big Four, Lake Shore, and other lines. Fifty per cent of the entire population of the United States and Canada lies within a radius of 500 miles of Cleveland. If one considers with this fact the enormous commercial and industrial importance of Cleveland and its excellent railroad and steamship facilities, the necessity is obvious of securing and maintaining a high standard of sanitary excellence in Cleveland for the conservation of the public health.

Housing and other conditions of a sociologic or economic character are better than the average in Cleveland. The great area covered and its 684 miles of streets militate against overcrowding, and its industrial activity is responsible for more than ordinary prosperity among the poorer classes.

*Sewer system.*—All of Cleveland's sewage goes directly or indirectly into the lake. Fifty-two per cent of it is discharged into the Cuyahoga River. Forty per cent is now being discharged into Lake Erie at outlet No. 2, through which ultimately all of Cleveland's sewage is to be discharged, according to present plans. The remaining 8 per cent is discharged at West Fifty-eighth Street into the harbor.

Map 13 was prepared from data furnished by the city engineer of Cleveland. The intercepting sewer is indicated by a heavy line where completed, the projected interceptors by a broken line. The interceptor from One hundred and sixteenth Street to Fifty-eighth Street on the west side is completed. This will be continued from West Fifty-eighth Street to the Cuyahoga and under the river to join the east-side interceptor. The east-side interceptor is completed from the river to outlet No. 2. Proposed interceptors as indicated on the map will eventually take the rest of the sewage from the Cuyahoga River to the main interceptor at Twentieth Street east. Sewage from the irregularly shaped low lying district near the Cuyahoga will have to be pumped to the proposed interceptors.

This system when completed will carry all of Cleveland's sewage from the river and harbor outlets to an outfall 9 miles east of the harbor and a considerable distance from shore. The old sewer outlets indicated on the map will serve as storm-water outlets.

*Population per acre of sanitary drainage districts and per cent of total sanitary flow.*

| Name of district. | Outlet into— | Population per acre. | Per cent of total sanitary flow. |
|---|---|---|---|
| West Forty-fifth Street | Cuyahoga River | 22 | |
| West Twenty-fifth Street | do | 110 | |
| West Ninth Street | do | 110 | |
| Do | do | 22 | 52.2 |
| Walworth Run | do | 22 | |
| Kingsbury Run | do | 22 | |
| Broadway and Morgan Run | do | 22 | |
| Low-level district | do | | |
| West Ninth Street | Lake Erie | 110 | |
| West Third Street | do | 110 | |
| Ontario Street | do | 110 | |
| West Ninth Street | do | 110 | |
| East Twelfth Street | do | 110 | |
| Do | do | 22 | |
| East Seventeenth Street | do | 22 | |
| East Twenty-sixth Street | do | 22 | |
| East Thirty-third Street | do | 22 | |
| East Thirty-eighth Street | do | 22 | 40.4 |
| East Fortieth Street | do | 22 | |
| Marquette Street | do | 22 | |
| East Fifty-fifth Street | do | 22 | |
| East Sixth-first Street | do | 22 | |
| Addison Road | do | 22 | |
| East Seventy-ninth Street | do | 22 | |
| East Eighty-eighth Street | do | 11 | |
| East Ninety-sixth Street | do | 22 | |
| East One hundred and tenth Street | do | 11 | |
| Dugway Brook | do | 11 | |
| West Fifty-eighth Street | do | | 8.3 |
| Grand total | | | 100 |

*Milk.*—The sanitary control of milk in Cleveland is exercised by the board of health. Every farm furnishing milk to the city is inspected and rated by the score-card system. The dairies in the city are licensed under strict regulations, and their licenses are revoked if regulations are not complied with. By an intercity agreement with Pittsburg, Cincinnati, Columbus, Indianapolis, and other cities, Cleveland protects itself from condemned milk from these cities.

The sanitary control of milk in Cleveland is rather above the average, and Cleveland has progressed in the solution of this problem quite as far as any of the other large cities. While supervision and inspection, as in other large cities, is not perfect, the work done

by the Cleveland board of health makes it unlikely that milk plays anything more than a minor rôle in the transmission of typhoid fever.

*Garbage.*—The collection of garbage in Cleveland is under municipal control. The garbage is collected separately from refuse and ashes and conveyed to a reducing plant.

*Water supply.*—The first general use of lake water dates back to 1853, when an intake was placed a few hundred feet from shore and about one-half mile west of the mouth of the river. About 1860 refuse from the oil refineries affected the water supply, and it was decided to place an intake crib 1⅓ miles from shore and about 1 mile west of the river mouth. Two tunnels were constructed, one in 1874 and one in 1891, to bring the water from the intake to the Division Street pumping station. This system was used as a public water supply until 1904. This old intake crib was subject to frequent pollution with sewage. One of the largest sewers discharged at the foot of West Fifty-eighth Street within the harbor near the western breakwater. The water in this end of the basin in consequence became very foul, and to relieve the nuisance an opening was made in the western boundary of the harbor, which permitted this sewage to pass out of the harbor to the lake and incidentally to the waterworks intake, in a much more direct manner than by way of the main harbor entrance.

To secure a better supply, in 1896 work was begun upon a new system. The intake was placed 4 miles from shore and nearly opposite the mouth of the Cuyahoga River. The water is taken from 10 to 28 feet below the surface and 22 feet above the bottom. A 9-foot tunnel connects the intake with the pumping station at Kirtland Street. Based on a flow of 4 feet per second, the nominal capacity of the tunnel is estimated at 175,000,000 gallons daily. This system was inaugurated in April, 1904, and is in present use.

TYPHOID FEVER.

During the period from 1873 to 1904 there was a persistently high typhoid fever death rate in Cleveland. (Chart XLVI.) Many of these typhoid outbreaks occurred in the winter months and were probably waterborne. Whipple [1] noted that in Cleveland outbreaks of typhoid fever occurred 10 days or 2 weeks following flood in the Cuyahoga and a strong south or southeast wind. It seems that a rise in the lake level at Cleveland checks the impetus which flood gives to the sewage-laden water of the Cuyahoga, but that a falling lake level at Cleveland, coupled with flood in the river, produces conditions which permit sewage to be carried quickly from the mouth of the river well out in the lake. The velocity of the stream prevents any great amount of dilution or diffusion, and the stratified polluted current is often carried

[1] Whipple, Geo. C., Report on the Quality of the Water Supply of the City of Cleveland, Ohio, July 1, 1905.


CHART XLVI.

Note the drop coincident with moving the intake 4 miles out from shore in 1904.

for miles before diffusion and dilution actually take place. This condition seems to be accentuated by the presence of ice—probably because the ice prevents wind action interfering with the river water in its course toward the intake.

The epidemics of 1903 and 1904 were winter and spring epidemics. In both these years the great bulk of the deaths from typhoid fever occurred in the first six months of the year; March and April had the greatest number of deaths in 1903, and February and March in 1904. In April, 1904, the new intake was put in service and the coincident drop in typhoid fever death rates was striking.

*Deaths from typhoid fever per 100,000 population, 1901–1905.*

| | | | |
|---|---|---|---|
| 1901 | 37.6 | 1904 (January to June) | 71.6 |
| 1902 | 31.6 | 1904 (July to December) | 20.0 |
| 1903 | 108.5 | 1905 | 14.25 |

In 1905 the rate dropped to 14.25; in 1906 it rose to 19; but in 1908 and 1909 it was 12.20 and 12.35, respectively. In 1910 it rose again, and the rate will be above 18 per 100,000.

A close study of conditions in Cleveland and of the records and data available for the period previous to April, 1904, will convince anyone that water was responsible for the undue prevalence of typhoid fever.

The great improvement in the typhoid death rate beginning with the installation of the new four-mile intake created the impression in some quarters that the problem was solved and that the typhoid remaining was residual typhoid, or typhoid due to other causes than water.

This impression gained ground in 1907, 1908, and 1909, when low rates could be cited as proof that the water supply was above reproach.

It is deemed safer to base conclusions upon the record of deaths than upon reported cases of typhoid fever. The reason for this is obvious: At no time in the year do the reported cases bear the proper ratio to deaths. In the winter months in most cities the number of deaths at times almost equals the number of cases reported, and frequently indicates a case mortality of 50 per cent. On the other hand, in September and October physicians are on the alert for typhoid; more cases are expected, and often this expectancy results in reporting cases which ordinarily escape observation.

The ratio of reported cases to deaths approaches the normal in American cities not only during the so-called typhoid season, but also whenever an epidemic convinces the doubtful ones that typhoid exists. At other times the public mind is made up that there should be no typhoid, and diagnosis is made reluctantly, when this conviction is overcome by symptoms which can not be mistaken. When we consider the great number of light and atypical cases of typhoid, as well as other diseases, it is not strange that at such times many cases go unrecognized or unreported.

For example, in Cleveland in 1907 the following cases and deaths were reported: In January, 15 cases and 11 deaths, indicating a case mortality of 73 per cent; in September, 122 cases and 7 deaths, a case mortality of less than 6 per cent. That such differences in mortality really exist is inconceivable. The mortality probably varies little. Even in hospital cases it is about 10 per cent, and this is undoubtedly higher than the actual mortality if the light cases were discovered and included.

Fatal cases are more apt to be correctly diagnosed, at least at the time of writing the death certificate. Further, they can not escape observation, and the large majority of typhoid deaths are reported. Under these circumstances the only safe thing to do is to use the deaths as a basis, and by multiplying the number of deaths by 10 or 12 the approximate number of cases can be estimated. These estimates are more nearly correct if the date be set back to cover the time during which the disease existed before death, a period of from three to four weeks.

In reaching the conclusion that Cleveland's typhoid was residual and not waterborne, two very important facts were overlooked, viz: (1) An average for 5 years of 15 per 100,000 is a low rate compared with American cities only, and is not a low rate compared with European cities with safe water supplies. (2) Typhoid fever not due to water does not show its greatest intensity in February, March, or April.

Chart XLVII shows typhoid fever cases estimated by multiplying the number of deaths by 10 by months during the year 1907.

The high rates of typhoid fever for January and May will be noted. As this chart is based upon deaths reported, the undue prevalence of typhoid fever really existed in December, 1906, and April, 1907.

Chart XLVIII shows typhoid fever deaths in Cleveland compared with typhoid deaths in New York City. As New York has about ten times Cleveland's population, Cleveland's deaths are multiplied by 10.

It is conceded that New York's typhoid is not due to water and is a typical residual infection, which includes imported and contact cases. The difference in the two curves is remarkable. Cleveland in 1910 shows two very sharp rises, one in January and the other in April. The real prevalence, of course, was probably in December, 1909, and March, 1910.

March has always been a notorious typhoid month in Cleveland. Conditions which favor increased pollution at the intake are most likely to exist in March.

Although cases reported in Cleveland are probably less than 60 per cent of the total cases existing, the cases reported for March, 1911, indicate a prevalence of typhoid fever greatly in excess of cases reported in any March since 1904.

*Cases of typhoid fever reported for the month of March, 1904–1911.*

| | | | |
|---|---|---|---|
| 1904 | 503 | 1908 | 24 |
| 1905 | 12 | 1909 | 30 |
| 1906 | 13 | 1910 | 38 |
| 1907 | 7 | 1911 | 46 |

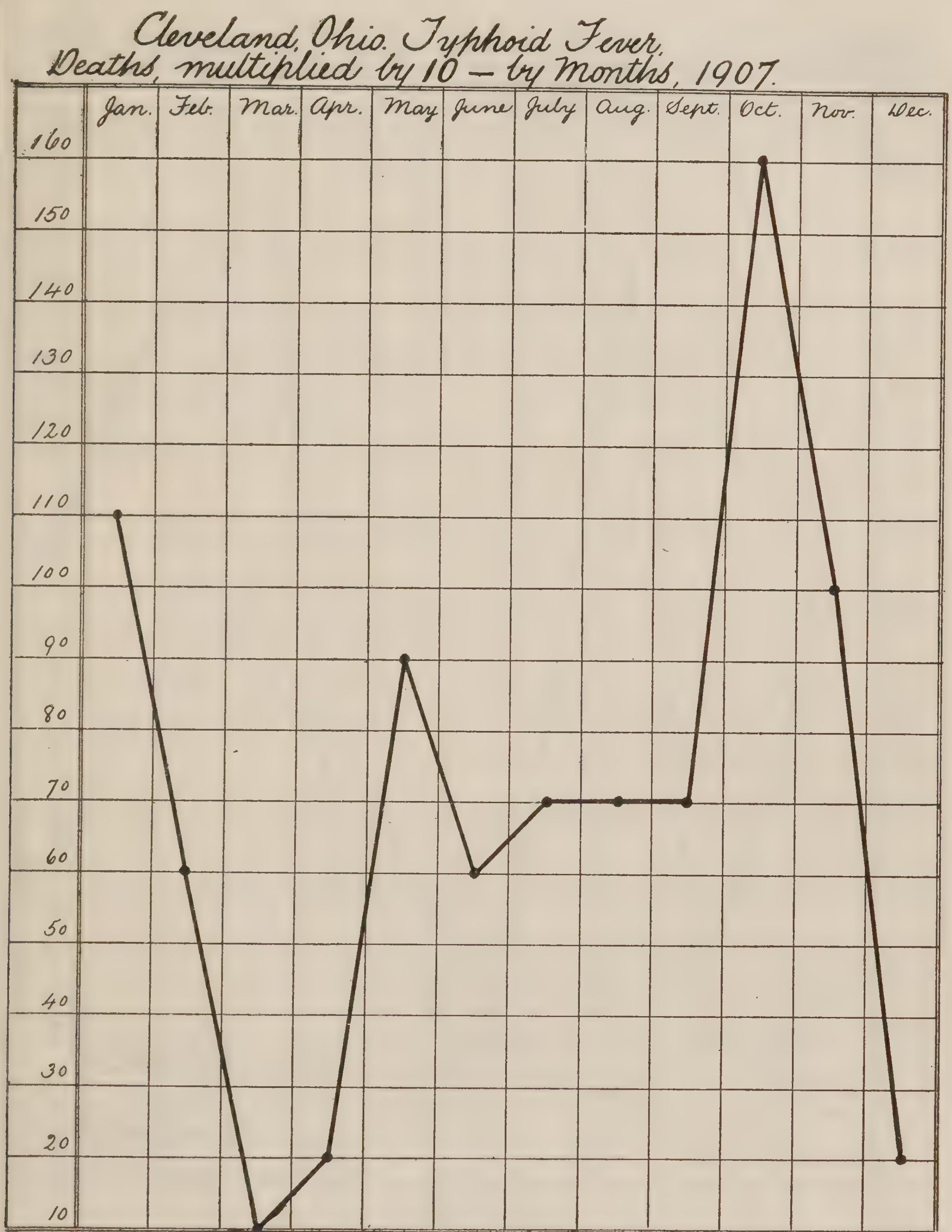


CHART XLVII.

Note the prevalence in January and May in addition to the autumnal rise.

The above indicates that after the installation of the 4-mile intake in 1904 the cases in March, a month of flood in the Cuyahoga, were less each year until 1907, showing temporary improvement effected

by moving the intake farther out. Since 1908 the number of cases in March has been progressively greater each year. As March is an ideal month for water-borne typhoid, and other factors favoring increased prevalence of typhoid except milk are negligible quantities

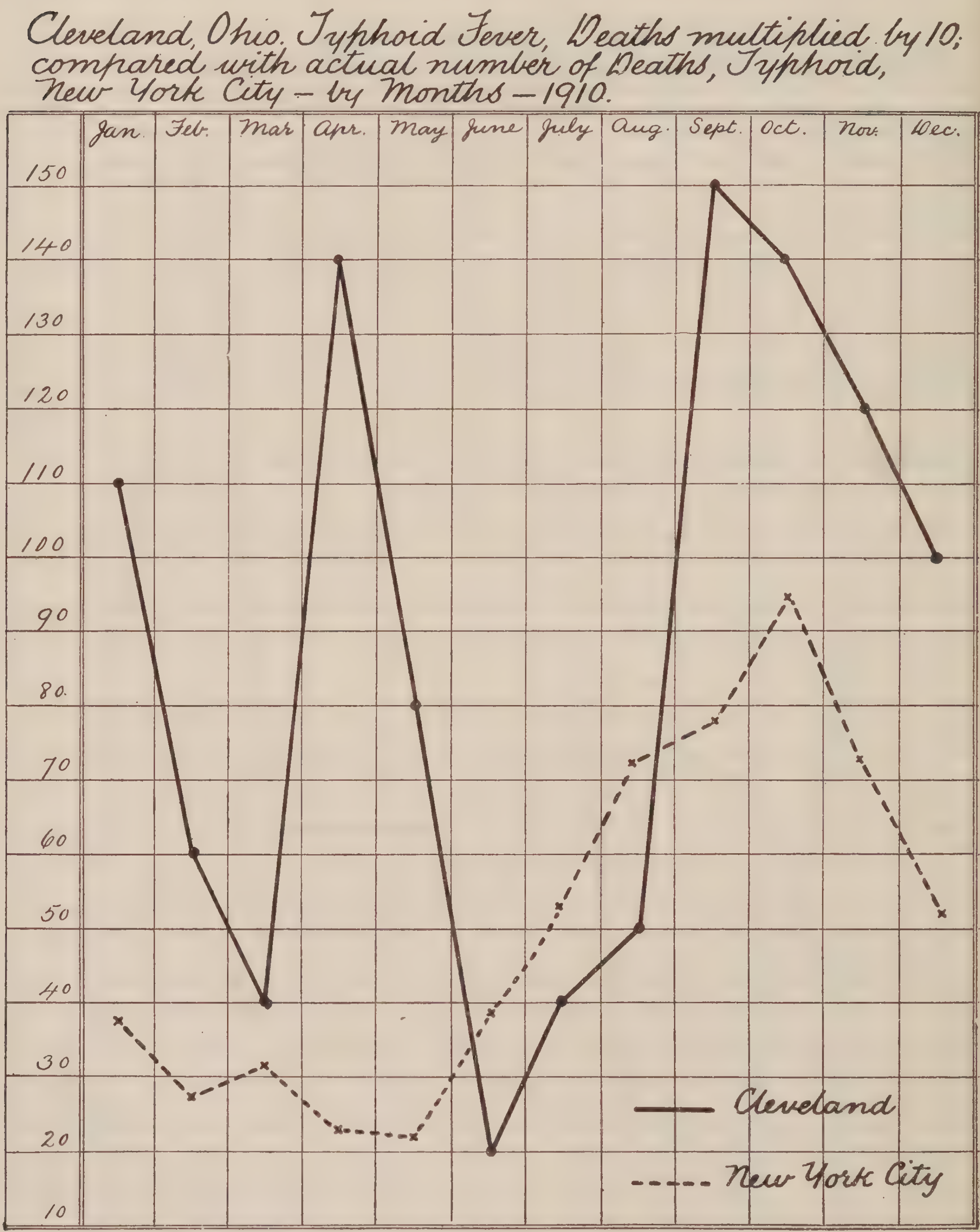


CHART XLVIII.

in March, the conclusion is unavoidable that the record indicates progressively increasing pollution at the new intake.

Chart XLIX shows typhoid fever cases during 1910 by seven-day periods. This chart was prepared from data furnished by Dr. Roger G. Perkins, professor of hygiene, Western Reserve University, of


CHART XLIX.

Note the explosive outbreak with apex the first week in April, the highest of the year.

Cleveland. This shows an outbreak of explosive character occurring the last week in March and the first week in April. Dr. Perkins made a careful scientific study of this outbreak. His qualifications for epidemologic studies give great weight to his findings and conclusions, and I take the liberty of quoting freely from his paper.[1]

Dr. Perkins makes the following observations upon pollution of the Cleveland water supply at the intake and upon the outbreak of March and April, 1910:

Correspondence shows that authorities who are in a position from actual personal work to know the conditions agree that the waters of the Great Lakes, where sufficiently distant from human pollution, are of good quality, and should contain no fermenting bacteria. Further correspondence with prominent bacteriologists shows a prevailing opinion that over 90 per cent of all organisms in water which are able to ferment lactose with the formation of gas belong to the group of intestinal bacteria. This agrees with the results obtained at the city bacteriological laboratory in the last few years and with my personal experience, so that although at certain times there has been insufficient help in the laboratory to carry out the differential diagnosis of the lactose fermenters, I have assumed that when these were present sewage contamination was thereby indicated.

Daily tests since 1904 in the city bacteriological laboratory show that while the findings of lactose-fermenting organisms in the first period following the change in the water were few and far between, they have of late years markedly increased, so that it is rare to find a week when there is not at least one day with fermentation in the 10 cubic centimeters lactose-bile fermentation tube. Chemical tests over the same period, though not as frequent, indicate irregular pollution by chemicals characteristic of sewage. We have then the gross pollution of the lake some 4 miles from the intake, and the laboratory indication that this pollution reaches the intake at least part of the time.

One of the very important points in regard to this especial epidemic is that at the time of the gross pollution of the water there was at the same period definite evidence of the presence of wastes from the Standard Oil Co. works which could have come only from the river, showing beyond doubt that river water in large amounts can reach the intake under favorable weather conditions.

The mass of the pollution, at least 52 per cent, passes into the Cuyahoga, and it is worth noting that this sewage comes from the least sanitary parts of the city, the districts where typhoid from other causes than water is most apt to be endemic and where the doctor is less frequently called in. In addition to the known sewage there is a large amount of gross pollution from the shipping in the harbor and in the river, which can never be adequately controlled, and an additional pollution from various trade wastes from the industries along the river, such as the Standard Oil Co. works. These last, as well as the pollutions from higher up the river, will not be removed even at the completion of the contemplated intercepter, leaving the river still a polluted stream.

The result, as far as the river is concerned, is that the stream is nothing more than an open sewer, and with the many docks and side branches, forms a series of septic tanks where active putrefaction may be seen and smelled in the summer months. The odor is so offensive that the lake passenger boats are trying to make arrangements to dock outside of the river, partly on account of the complaints from the passengers. This collection of putrefying material, to which are added trade wastes of various types, some of them of such a character that the surface of the river has been several times in flames, is always present except immediately after floods have swept it out into the

[1] Perkins, R. G., M. D., "Typhoid fever in Cleveland in relation to pollutions of Lake Erie." Cleveland Medical Journal, February, 1911, Vol. X, p. 81.

lake to make room for a new supply. At the lower part, the river is a fresh-water estuary and its level is determined by the level of the lake, which is, again, determined almost entirely by the direction of the winds. It is therefore evident that any variation in the amount of water entering the river will make a corresponding variation in the speed of outflow into the lake, especially if the change in volume is a sudden one.

The 52 per cent of the total sewage will therefore in times of heavy rain or thaw receive an impulse directly outward toward the intake. After the water and sewage reach the lake there are other factors which enter into the calculations. The crib is directly opposite the opening of the river and the opening of the breakwater, and the normal tendency in the absence of the other factors would be a gradual diffusion and sedimentation in a sort of fan shape, so that before the 4 miles had been traversed the greater part of the sediment would be settled and there would be a sufficient time interval for the destruction of a large number of the bacteria. As shown by Whipple, the currents in the bay opposite Cleveland are practically dependent on the wind, so that on the prevalence of one wind or another would depend the trend of the sewage. South or southeast winds would obviously be most dangerous, and inasmuch as the greater part of the rain comes with these winds, it may be seen that these two factors work together. On the other hand, north or west winds tend to clear the vicinity of the crib from the local influences.

It must be remembered, however, that Lake Erie is shallow, and that in case of a strong north or west wind there is a marked reverse undercurrent established which is also dangerous. When therefore there is the combination of a wind from the east or south and a marked increase in the flow of the river we have excellent opportunity for the transfer of pollution to the drinking water.

At times another factor is added to these. While the wind may be dangerous, it also helps somewhat in oxidation of the bacteria by stirring up the water and by establishing cross currents, horizontal or vertical, which modify the course of the sewage and tend to its greater distribution. At times, however, this influence is completely removed by the presence of a solid sheet of ice over the lake both inside and outside the breakwater. Under these conditions a sudden increase of flow of the river apparently tends to pass out directly north in a more or less unbroken stream, carrying the sewage directly to the intake.

The factors of safety, then, are dry weather, absence of ice, and moderate north or west winds. The factors of danger are sudden increases of flow in the river, sheet ice on the lake, or south and east winds.

These factors can be readily theorized, and it is necessary to correlate them with the facts relating on the one hand to the indicated pollution and on the other to the waterborne diseases.

If the premises are correct, we should find that when the danger factors are prominent we have increase of laboratory pollution and increase of typhoid. An additional factor must here be considered, that there must be the discharge of typhoid excreta in the river at the time of the development of the danger factors.

Taking this as a representative epidemic and keeping in mind the incubation period of typhoid, we see that in general a heavy rain lasting one or several days is followed by an increase in the turbidity and in the chemical and bacteriological pollutions. After two to three weeks there is a rise in the typhoid incidence, though during the actual course of the epidemic the water may be of unusual purity. The length of time between infection of the water and the development of the epidemic is of course due to the fact that as a rule cases are not reported for eight or ten days after onset. When the town is riddled with typhoid, and especially in the summer, when flies are active, the distribution is too great to allow us to get accurate etiological data, but there are at least two small epidemics with so sudden a rise and fall as to suggest some central cause, and these have been further analyzed.

*Summary and conclusions.*—1. The waters of Lake Erie for several miles north of the present intake are subject to sewage pollution and pollution from trade wastes.

2. These pollutions depend largely on weather conditions, notably such as cause increase in the flow of the Cuyahoga River, for the direction and extent of the area involved.

3. Present sewage outlets discharge over one-half of Cleveland sewage into the river.

4. Pollution will be decreased but not removed on completion of present sewer plans.

5. Many, if not all, of the distinct epidemics are caused by the water.

6. The interepidemic or endemic typhoid is probably not water borne.

7. Turbidity can be removed only by filtration.

8. Danger of infection can be removed only by filtration or disinfection.

9. It is recommended that plans for filtration of the supply should be prepared and that in the interval the water should be disinfected.

There can be little doubt of the existence of frequent pollution at the intake under present conditions, as shown by Dr. Perkins. It remains to be seen how much pollution will take place after present plans for intercepting and removing the sewage from the river are carried out.

These plans when completed will remove the 52 per cent of Cleveland's sewage now being discharged into the Cuyahoga and all the rest of the city sewage and discharge it at a point 8.2 miles eastward of the waterworks intake. Until these plans are executed their effect can only be conjectured. However, two things must be considered—first, pollution from sources outside of Cleveland itself, and, second, the effect of Cleveland's entire sewage discharged only $8\frac{1}{5}$ miles from the intake. In spite of the removal of Cleveland's sewage from the Cuyahoga, it will still be a grossly polluted stream. It drains a very populous watershed, including the city of Akron, and receives the pollution of the numerous vessels in the harbor.

Thirty miles west of Cleveland Lorain pours its sewage into the Black River at its mouth. Sandusky is 60 miles west of Cleveland. The enormous volume of water available for dilution and the time which must elapse in transit, owing to the distance and tendency of lake currents to change and oscillate back and forth, probably makes sewage from Sandusky harmless and that from Lorain of very slight danger. However, Lorain and other shore communities are growing, and pollution will increase rather than diminish.

East of Cleveland will exist the chief menace to Cleveland's water supply, viz, the proposed discharge of the entire sewage of the city 9 miles east of the harbor and $8\frac{1}{5}$ miles in a straight line east of the intake.

The chief factors in rendering innocuous sewage discharged in water are the amount of water available for dilution and the time factor, which depends upon the distance to be traveled and velocity and direction of currents.

The volume of water available for dilution of sewage discharged into Lake Erie near Cleveland is enormous.

The ability of the lake to render harmless large quantities of filth is well known. There must, however, be sufficient distance allowed for diffusion and sedimentation to take place and time enough to permit of death of the pathogenic bacteria present.

Lake Erie is a comparatively shallow lake; its normal current is so slight that it has been computed as one-eighth to one-sixth of a mile in 24 hours. Its real currents are the result of wind action and are quite as likely to be from one direction as another.

In discussing results of his investigation of Cleveland's water supply, Whipple made the following statement: [1]

> The completion of the intercepting sewer system by which the sewage of the city will cease to be discharged into the Cuyahoga River and into the lake along the water front and be carried to a point 9 miles east of the city will materially improve the sanitary quality of the lake water at both intakes, but will not absolutely prevent the pollution of the water at the new crib at all times and under all conditions.

He says further (p. 8, par. 8):

> After the completion of the intercepting sewer system the danger of pollution of the water at the new crib will gradually increase as the city grows until eventually the quality of the water may be affected by it to an appreciable extent.

Six years have elapsed since Mr. Whipple made this report, and in the meantime the growth of Cleveland has been very rapid.

The impression that a steady lake current exists from west to east is fallacious, and it can be demonstrated that a very strong current from east to west frequently pertains. Weather conditions at Cleveland affect the lake similarly to those described at Buffalo and Erie. Following southwest winds or gales and a very low stage at Amherstburg and Toledo there takes place a rapid return of the water from east to west to equalize the lake level, with a strong current past Cleveland from east to west. Strong northeast winds or gales can produce a somewhat similar result by piling up the water at Toledo and Amherstburg. Under certain conditions with a strong current from east to west the distance, $8\frac{1}{5}$ miles, is not great enough to permit sufficient diffusion and sedimentation of sewage to render it innocuous. Under such conditions some diffusion and consequent dilution would, of course, take place, but sufficient time would not elapse in the transit of $8\frac{1}{5}$ miles with a rapid current to permit any great degree of sedimentation. Further, the time of transit would be obviously not sufficient to permit of death of pathogenic organisms. Pollution of the intake with Cleveland's sewage discharged $8\frac{1}{5}$ miles east of the intake is possible, and under certain weather conditions would be extremely probable.

The velocity of this current will depend in the case of southwest winds upon the amount of disturbance of lake level which preceded

[1] Report of George C. Whipple on the Quality of the Water Supply of the City of Cleveland, Ohio, July 1, 1905, p. 8, par. 6.

it. In the case of northeast winds or gales it will depend upon the velocity of the wind. Many other currents of irregular course and obscure origin undoubtedly exist, and it is safe to assume that sewage potentially infective may travel westward in Lake Erie a distance greater than 8⅛ miles under certain weather conditions.

What would be the result of pollution under such circumstances? In the first place, it would be a very dilute pollution and unlikely to cause a great explosive outbreak. That such a pollution, however, would be quite capable of causing many cases of typhoid fever can not be denied.

### LORAIN.

Prior to 1895 the water supply of Lorain was taken from Lake Erie 1,200 feet from shore and a little to the west of and distant only about one-quarter of a mile from the mouth of the Black River. Lorain at that time had a population of about 10,000 and sewered direct into the Black River.

Elyria, situated 7 miles above Lorain on the Black River, had at that time (1895) a population of 7,000, and discharged its sewage direct into the Black River. The unfiltered lake water was used in Lorain with the intake protected from the sewage-laden water of Black River only because of winds and currents prevailing during a part of the year, and exposed to gross pollution during times of flood and northeast or easterly winds. Under these conditions it was not strange that Lorain suffered severely from typhoid fever. In the report of the Ohio State Board of Health for 1895, Dr. Cox, health officer of Lorain, furnished a statement concerning typhoid deaths in Lorain. According to Dr. Cox, sewers were first constructed in Lorain in 1892. Previous to their construction deaths from typhoid were such as usually occur in a town of 5,000 inhabitants where no special contamination of water supply exists. The few deaths which actually occurred and the cases of typhoid noted occurred in the fall of the year, or the regular typhoid season. Up to this time, then, the purifying agencies of the river and lake seem to have been sufficient to render innocuous the sewage of Elyria so far as Lorain's intake was concerned.

With the discharge of Lorain's own sewage, comparatively small in quantity but discharged near the intake, serious pollution of Lorain's water supply evidently took place. A small amount of recent pollution near an intake is a greater menace than a large amount of pollution entering the stream several miles above.

As an instance of this the city of Elyria discharged its sewage into the Black River above Lorain about 10 miles from Lorain's intake in Lake Erie. In dry weather the rapids and pools permitted natural agencies to render innocuous Elyria's sewage. In flood times sufficient dilution was evidently furnished by the volume of the river

so that Lorain apparently did not suffer from polluted water and winter typhoid epidemics until after 1892, when Lorain installed a sewerage system and discharged sewage into the Black River within 1,800 feet of its mouth. In most of the rivers emptying into Lake Erie there is great variation in stream flow according to season. A

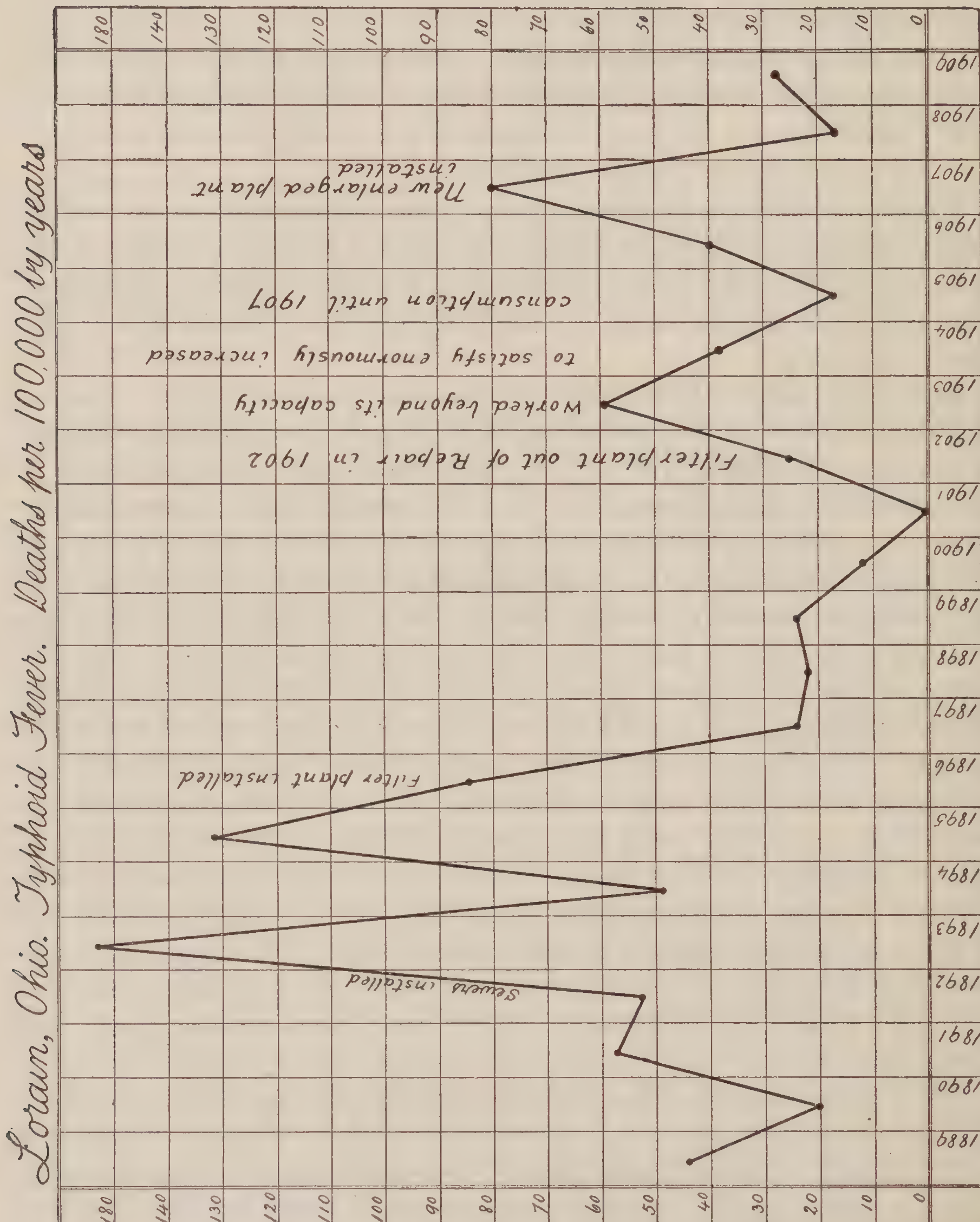


CHART L.

stream which in flood discharges 10,000 to 20,000 cubic feet per second in dry weather discharges as low as 40 to 50 cubic feet per second. In dry weather the current is very sluggish and carries but a short distance into the lake. Further, the lessened flow converts these rivers into a succession of pools and rapids which are really sedimen-

tation and aeration apparatus. Septic action also goes on in the stagnant places, and if the minimum flow necessary for dilution (variously estimated at about $3\frac{1}{2}$ to 7 cubic feet per second for each 1,000 of population) is not furnished, local nuisance results.

However, at this time there is slight danger of sewage contamination of an intake placed well out from shore and to the westward of the mouth of the river. In flood time the immensely increased stream flow, reaching perhaps 20,000 cubic feet per second, scours out these sedimentation basins and carries fresh sewage speedily to the lake. The velocity is such that stratification of the polluted water is preserved far out into the lake and there is no opportunity for either dilution or sedimentation until the lake is reached. The further direction of the polluted current depends upon the lake winds and currents, which, as shown above, are extremely variable and during these periods of storm and flood are quite as likely to be toward the intake as away from it.

The following table was prepared by Mr. George E. Rafter, consulting engineer, from data furnished by Dr. Cox, and shows the prevalence in February, March, and April, and the comparatively few deaths in August, September, and October after the installation of a sewerage system:

| Months. | 1889 | 1890 | 1891 | 1892 | 1893 | 1894 | 1895 |
|---|---|---|---|---|---|---|---|
| January | | | | | 1 | | |
| February | | | | | | | 3 |
| March | | | | | 2 | 1 | 2 |
| April | | | | | 6 | | 4 |
| May | | | | | 1 | | 1 |
| June | | | | | | | 0 |
| July | | | | | | | 0 |
| August | | 1 | | | | 2 | 0 |
| September | 1 | | 1 | 1 | | | 3 |
| October | | | 2 | | 1 | 1 | 1 |
| November | | | | 2 | | | 1 |
| December | 1 | | | | | | 0 |
| Total | 2 | 1 | 3 | 3 | 11 | 4 | 15 |

As a result of the prevalence of typhoid and the implication of the public water supply in its causation, the city of Lorain installed a mechanical (Jewell) filtration system in 1896. In 1897 Allen Hazen, consulting engineer, reported upon these filters. His report showed the following filter efficiency:

First. The removal of nearly half the organic matter and all color turbidity sediment and odor.

Second. Removal of 98 per cent of bacteria when filtered at the rate of 1.1 gallons per square foot per minute and with the use of 2.5 grains of alum per gallon.

Third. Removal of 90 per cent bacteria with a filtration rate of 1.2 gallons per square foot per minute, using 1 grain of alum per gallon.

Fourth. Alum was completely decomposed and did not appear in the effluent.

In approving these filters Dr. C. O. Probst, secretary of the State Board of Health of Ohio, said:

I have to recommend, therefore, that the change in the water supply of Lorain be approved, subject to the conditions that the maximum rate of filtration be 100,000,000 gallons per acre daily, and that not less than 2.5 grains of alum per gallon be used.

While recommending approval, I would suggest that the attention of the authorities at Lorain be called to the fact that their filters during other seasons of the year may be subjected to a severer trial than the one here reported; that so long as sewage is turned into the Black River the consumers of the lake water have to depend upon the honest, intelligent operations of these filters to protect them against disease; that the results of filtration can be known only by daily bacteriological examinations, for which provisions should be made. I would add further that it be suggested that the best interests of the city demand that an effort be made to free Black River from sewage pollution; and that it be pointed out that, if this is not done, it may be found advisable that the waterworks intake be extended to a point where the danger from pollution is not so great.

Even this early (1897) Dr. Probst clearly appreciated the danger from careless operation of mechanical filters either from too little coagulant or from too great a rate of flow. He did everything in his power to impress the authorities of Lorain with their responsibility in this matter, but the conditions imposed were not carried out.

In spite of the fact that the amount of alum required by the State was reduced to less than 1 grain per gallon, the effect of filtration upon the typhoid rate was striking during the first years of operation, 1897 to 1901.

*Typhoid death rate per 100,000 of population at Lorain, 1893–1901.*

| | | | |
|---|---|---|---|
| 1893 | 183 | 1898 | 21 |
| 1894 | 48 | 1899 | 24 |
| 1895 | 131 | 1900 | 12 |
| 1896 | 83 | 1901 | 0 |
| 1897 (filter installed) | 24 | | |

In 1900 the State board of health granted permission to experiment with copperas. This seemed to work well in 1900 and 1901, but after two years, parts of the machinery and the strainers of the filters were practically destroyed by the chemicals, and it is significant that in 1902 the typhoid rate rose again. After repair of the machinery even if a sufficient quantity of a suitable coagulant had been used, the very rapid increase in population nesessitated working the filters far beyond their capacity and an unsafe effluent was the result.

In 1903 the State board of health granted permission to the city to experiment with copperas and lime instead of alum as a coagulant

for a limited time, a daily report to be made to the State board. This report was favorable, and was made from June 8, 1903, to February 29, 1904. The State board of health disclaimed having given authority for the use unconditionally of iron and lime. However, it seems that the increase of typhoid and the dangerous quality of the water were due to the excessive rate of filtration rather than to the kind of coagulent used.


MAP 14.—Lorain, Ohio, showing harbor and existing waterworks intake.

Proposed new intake and proposed extension of the west breakwater to the beach is expected to furnish a raw water for the filters with a much lower bacterial count. The proposed extensions of the intake pipe and breakwater are shown by dotted lines.

*Typhoid death rate per 100,000 of population at Lorain, 1901–1907.*

| | | | |
|---|---|---|---|
| 1901 | 0 | 1905 | 16 |
| 1902 | 25 | 1906 | 40 |
| 1903 | 59 | 1907 | 80 |
| 1904 | 38 | | |

January, 1906, the State board of health approved plans for a proposed new filter plant for the city of Lorain, as shown on drawings submitted to the board by the Pittsburgh Filter Manufacturing Co., on September 7, and October 28, 1905, provided that the management and operation of the plant, the use of the coagulant, and the method of controlling the rate of filtration be subject at all times to the approval of the State board of health; also to call the attention of the authorities to the fact that the present and proposed facilities for storing filtered water were not sufficient to allow for any considerable increase in the water consumption, and that unless greater storage capacity were provided the new filter plant, as in the case of the old one, would within a few years be operated at excessive rates at times and poor results would be obtained.

These filters were of much larger capacity and were installed in 1907.

The Lorain filter plant has a capacity of 6,000,000 gallons. It is a mechanical or rapid sand system. This is double the capacity of the old plant.

Safety from water-borne typhoid at Lorain depends upon the efficiency of the filters, as a result of intelligent supervision. They are now struggling with raw water which at times is very grossly polluted. Certain projected improvements will give a better raw water. As shown on the accompanying map, the west breakwater is to be continued south to the shore, thus inclosing the present intake and making the conditions surrounding the intake very much worse than at present.

To offset this a new intake is to be placed outside the breakwater, in 26½ feet of water, 1,160 feet from the filter plant. The new intake will be connected to the filter plant by a 4-foot intake pipe. It is expected that the new intake will be completed by July, 1911.

### ELYRIA.

Elyria, Ohio, has a population estimated at 15,000 and is an attractive residence city, in direct communication by electric cars with Cleveland, Oberlin, and Lorain. It is well sewered, the outlets discharging into Black River. Previous to 1904, Elyria derived its water supply from the west branch of Black River, by means of two impounding dams. The capacity of the impounding reservoirs thus created was large, but the opportunity for serious pollution was present and almost unavoidable. The surface drainage from Oberlin, Lagrange, Rochester, and Wellington, the effluent from the Oberlin sewage farm, and the sewage from the county infirmary all entered the stream a comparatively short distance above the reservoirs.

In 1903 Elyria decided upon a new supply and the plans were approved by the State board of health January 4, 1904. The supply is taken from Lake Erie. The intake is situated 1,500 feet from shore, and 3 miles west of Lorain, Ohio. The system is mechanical filtration with the use of a coagulant.

In approving the plans, the State board of health specified that a competent bacteriologist be employed for two months to make daily analyses and to instruct those in charge as to proper care of filters and amount of coagulant to be used. The State board of health reserved the right to require higher standards of efficiency, and change in methods of operation or coagulant if necessary.

The success of the filtration of Lake Erie water as a source of supply for Elyria depends upon the filter efficiency which can be maintained by the supervision of the State authorities, as provided for wisely in the formal approval granted by the State board of health.

Two tables are appended, showing deaths from typhoid fever and from colitis for 11 years, 1900–1910, by months. The cause of the latter disease being obscure, it is not unlikely that some of these cases were typhoid. These tables do not show an excessive typhoid rate and the bulk of the cases occurred from August to November. Only one case in two years occurred in any month from December to July. The filters are not operated at a rapid rate and good filter efficiency is probably maintained.

*Deaths from typhoid fever in Elyria, Ohio, from January, 1900, to April, 1911.*

| Months. | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January |  |  |  |  |  | 1 |  |  |  |  |  |  |
| February |  |  | 2 |  |  | 1 |  |  | 1 |  |  |  |
| March |  |  |  |  |  | 1 |  |  |  |  | 1 |  |
| April | 1 |  |  |  |  |  |  |  |  |  |  |  |
| May |  |  |  |  |  |  |  |  |  |  |  |  |
| June |  |  |  | 3 |  |  |  |  |  |  |  |  |
| July |  |  | 1 |  |  |  |  |  |  |  |  |  |
| August |  | 1 |  |  |  |  |  | 1 |  |  | 1 |  |
| September |  |  |  |  |  |  | 3 |  |  | 1 | 1 |  |
| October |  | 1 | 1 |  |  | 1 | 1 |  |  | 1 |  |  |
| November |  | 1 | 1 |  | 1 | 1 |  |  |  |  | 1 |  |
| December |  | 1 |  |  |  |  |  |  |  |  |  |  |

*Deaths from colitis in Elyria, Ohio, by months, 1900 to 1911, that might be of typhoid nature.*

| Months. | 1900 | 1901 | 1902 | 1903 | 1904 | 1905 | 1906 | 1907 | 1908 | 1909 | 1910 | 1911 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| January |  |  |  |  |  |  |  |  |  |  |  |  |
| February |  |  |  |  |  |  |  |  |  | 1 |  |  |
| March |  |  |  |  | 1 |  |  |  |  |  |  |  |
| April |  |  |  |  |  |  |  |  |  |  |  |  |
| May |  |  |  |  |  |  |  |  |  |  |  |  |
| June |  |  |  |  |  |  |  |  |  |  |  |  |
| July |  |  |  |  |  |  |  |  |  |  |  |  |
| August |  |  |  |  |  |  |  |  |  |  |  |  |
| September |  | 1 | 1 | 2 |  |  |  | 2 |  |  |  |  |
| October |  | 1 | 1 | 1 |  |  |  |  |  |  |  |  |
| November |  |  |  |  |  |  |  |  |  |  |  |  |
| December |  |  |  |  |  |  |  |  |  |  |  |  |

### VERMILION, OHIO.

Vermilion is a small village, with a harbor formed by dredging and protecting the mouth of Vermilion River by breakwaters. There is no ore or coal shipping at Vermilion; shipbuilding has declined, and fishing seems to be the only industry about the harbor.

There is no system of sewers. The waterworks consists of a lake intake and a small filter plant of the old Jewell type. The plant is small, but there is no necessity for overworking it, because of the small population supplied.

### HURON, OHIO.

The village of Huron is situated at the mouth of the Huron River. The channel is extended by means of breakwaters about 1,700 feet beyond the natural mouth of the river.

A 19-foot channel is maintained from the open lake between the breakwaters and for a considerable distance within the mouth of the river. In this way a small but excellent harbor is made available at Huron. Huron has a population of about 2,000. It has a terminal of the Wheeling & Lake Erie Railroad and will probably develop, because of its harbor and railroad facilities, as a receiving and distributing port for ore and coal. The ore-handling plant and dock at the mouth of the river represents the only industry of any importance in Huron.

Huron has no municipal water supply nor system of sewers. Shallow wells supply water and privies and dry vaults receive most of the excreta. In 1906 two sanitary sewers were installed, one of 12 and the other of 24 inch diameter. These ran on South and Main Streets and discharged by a common outfall on South Street into the Huron River.

Besides these sewers, several private drains discharge into the river. Villages of Norwalk and Milan above Huron also discharge wastes into the river. December 16, 1908, the State board of health approved a water supply system for Huron, with the understanding that approval was for the location of the intake only, and requiring filtration, complete plans to be submitted to the board for approval as soon as the same were prepared. The intake approved was to be placed 1,900 feet west of the westerly breakwater and west of the mouth of the first cove.

### SANDUSKY, OHIO.

Sandusky has a population of about 25,000 and is situated upon Sandusky Bay, one of the best natural harbors on the lakes. The city covers an area of about 6 square miles. The industries of Sandusky consist of a paper mill, planing mills, wine cellars, breweries, and some general manufacturing. The entire sewage of Sandusky is discharged untreated into Sandusky Bay.

The Sandusky River, a grossly polluted stream, empties into the shallow Sandusky Bay. The river has a length of 115 miles and drains a populous watershed of over 1,500 square miles. Its average discharge for the entire year is about 500 cubic feet per second,


Map 15.—Sandusky, Ohio, showing position of waterworks intake, exposed to pollution with Sandusky's own sewage.

although in January the maximum discharge may be well above 5,000 cubic feet per second.

There is a population on this watershed of over 100,000 persons including the cities of Tiffin, Bucyrus, and Fremont.

From the standpoint of waterborne diseases, the sewage pollution of Sandusky Bay by the discharge from the sewers of Sandusky is of vastly greater importance than the volume of polluted water carried from a great distance by the Sandusky River.

Sandusky's main water front faces the northwest, and upon this water front are found the bulk of the sewer outfalls. The northeast water front faces that portion of the bay southeast of the main channel and almost landlocked by Cedar Point. Into this portion of the bay less sewage enters directly than into the main portion of the bay facing the northwest water front.

The waterworks crib is situated in the southeast portion of the bay referred to above, 1,200 feet from the northeast water front in 7 feet of water. This portion of the bay had many advantages over other portions of this badly polluted body of water as a source of water supply.

It is a U-shaped body of water partly inclosed by the projection of Cedar Point and the mainland. The open end of the U is separated from the main bay by the 20-foot channel from the harbor entrance to the northwest water front. These boundaries inclose a sedimentation basin with very little inflow, protected to some extent from winds, and into which sewage pollution from the main harbor can enter only by crossing the current in or out in the 20-foot channel. So much for its natural advantages; unfortunately there are disadvantages which at times more than offset these.

Under quiet weather conditions the bulk of the inflow to Sandusky Bay, including the sewage discharged along the main or northwest water front, is carried by the current largely in the 20-foot channel to the open lake, with probably slight involvement of the water in the vicinity of the waterworks crib.

Other conditions could produce very different results. A northwest wind blowing for some time and of considerable velocity could readily blow the polluted water from the northwest water front to the southeast of the 20-foot channel and over the waterworks intake itself. Further, although not so great in amount, considerable sewage is discharged into this body of water direct. Some sewer outfalls exist 3,000 feet to the southeast of the intake and some of this sewage discharge must pass over the intake at times.

The question of pollution of Sandusky's intake is simplified by the shallow water. The depth is so slight that sewage-polluted water in the vicinity of the intake is almost equivalent to pollution of the water supply regardless of the question of surface currents and deep undercurrents which is so prominent where intakes are deeply placed.

The health authorities of the State of Ohio took cognizance of the dangerous character of the Sandusky water and in the annual

report of the State board of health for 1903 the following comment is found, after an examination of the water showed intestinal bacteria in five out of eight samples, using quantities of 1 cubic centimeter:

These findings by their marked increase over the normal of Lake Erie water show how objectionable the Sandusky supply is, because of its unsightly appearance, because of the organic matter it carries most of the time, and because of the danger there is of epidemic disease which may come with very slight modification of existing conditions.

It does seem that Sandusky has been especially fortunate to escape the serious affliction (epidemic typhoid fever) that has visited three of our Lake Erie cities in recent years, viz, Conneaut, Lorain, and Cleveland. How much better it would be if Sandusky would install a properly purified water supply before instead of after the sacrifice of many lives by a waterborne but preventable disease.

Sandusky evidently paid little attention to the warning of the State board of health. The suggestion that disaster be averted by the installation of a filter plant was not acted upon by the Sandusky authorities until five years later. The disaster predicted by Dr. Probst in 1903 really occurred in 1908 and 1909 as shown by Chart LI. As is usual in such cases, the filter plant was installed in 1909, after typhoid fever had totaled 700 cases and been responsible for the loss of 70 lives during 1908 and 1909.

*Cases and deaths from typhoid fever in Sandusky, Ohio, 1903–1911.*

| Years. | Cases. | Deaths. | Years. | Cases. | Deaths. |
|---|---|---|---|---|---|
| 1903 | 50 | 12 | 1909 | 335 | 35 |
| 1904 | 29 | 8 | 1910 | [1] 35 | 5 |
| 1905 | 21 | 3 | 1911 (January) | 53 | 2 |
| 1906 | 57 | 6 | 1911 (February) | 46 | 4 |
| 1907 | 49 | 6 | 1911 (March) | 11 | 2 |
| 1908 | 333 | 35 | | | |

[1] 14 imported.

The filter plant constructed is a mechanical or rapid-sand filtration system using alum as a coagulant.

It has serious structural defects. The sedimentation basins are too small to get the best results from sedimentation and the treated water reaches the filters very turbid with unsettled precipitate. For this reason the filters clog easily. The system, while built in units, has no provision for throwing any particular unit out of service without shutting down the entire plant. If repairs are necessary unfiltered water must be furnished.

This has resulted disastrously. December 15, 1910, the plant was shut down for repairs until January 9, 1911. As a result an epidemic of typhoid occurred beginning explosively within three weeks of the time when polluted water was furnished owing to the breaking down of the filter plant.

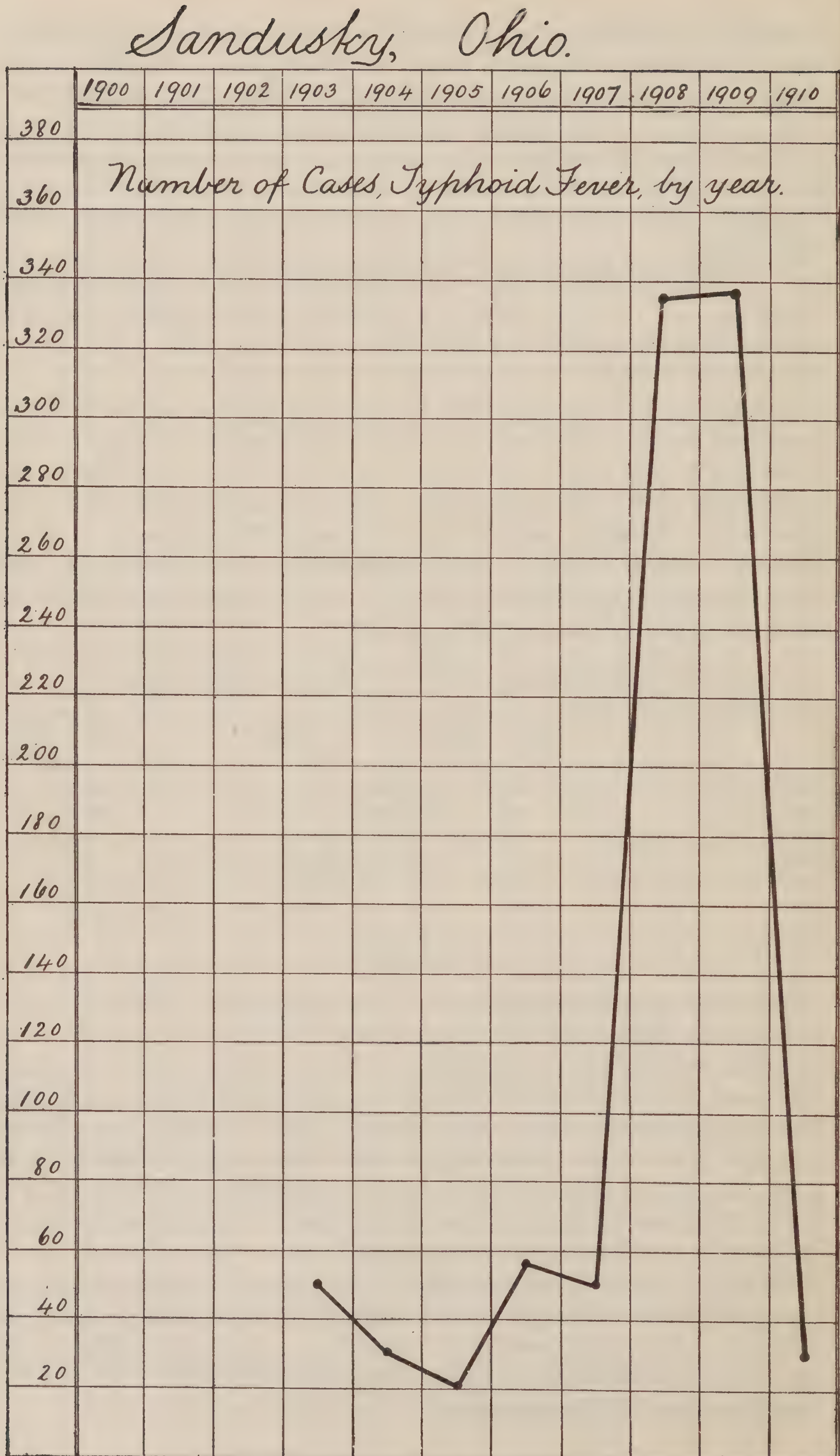


CHART LI.—Sandusky, Ohio, typhoid fever: Deaths per 100,000 by years, 1903 to 1910. The filter plant was installed in February, 1909.

*Cases and deaths from typhoid fever in Sandusky, Ohio, January to March, 1911.*

| Months. | Cases. | Deaths. |
|---|---|---|
| January, 1911 | 53 | 2 |
| February, 1911 | 46 | 4 |
| March, 1911 | 11 | 2 |

Filtered water was again furnished from January 9, and after a month the epidemic showed a tendency to subside. It is quite probable that the March cases were secondary.

The sedimentation basins are placed one on either side of the clear-water basin. I found large leaks from the corners of the sedimentation basins, and over the partition between one of the sedimentation basins and the clear-water basin a roaring sound could be distinctly heard. Upon calling attention to this the superintendent admitted that it was a leak and that the contractor would be notified at once. From the noise, the volume of water passing through must have been large.

The level in the sedimentation basin is high, and that of the clear well low because of the small storage capacity. It is clear that a leak existed from the sedimentation basin into the filtered water basin, and that a mixture of partially sedimented and filtered water was being furnished instead of filtered water to the consumers.

## TOLEDO, OHIO.

Toledo, Ohio, is situated near the mouth of the Maumee River, at the southwestern extremity of Lake Erie. In 1910 Toledo had a population of 168,497. Toledo's position, magnificent harbor and dockage facilities, and excellent railroad connections all combine to make it a desirable location for manufacturing and commercial pursuits.

Toledo possesses the advantages which transformed Cleveland, Buffalo, and Detroit into great cities. Its growth, according to census figures, has been phenomenal, as the following shows:

| | |
|---|---|
| 1880 | 50,137 |
| 1890 | 81,134 |
| 1900 | 131,822 |
| 1910 | 168,497 |

This rate of growth will probably be maintained if not exceeded in the future, and it is fair to estimate the population of Toledo as 250,000 in 1920.

*Water supply.*—The Toledo waterworks formerly had a pumping station (built 1873) on the river bank opposite Corbutt Island, with an intake in the river in the channel between Corbutt Island and the mainland.

The present intake is farther up the river, above Delaware Creek. The intake is 700 feet offshore in 20 feet of water.

The water is treated with alum and after eight hours' sedimentation is filtered by mechanical or rapid-sand filtration.

The Maumee River drains over 6,000 square miles of watershed, including the towns of St. Marys, Decatur, Findlay, Fort Wayne, Lind, Delphos, Van Wert, and Defiance. These towns have a combined population of over 100,000 people, and are situated at distances varying from 182 to 54 miles above Toledo. There is a large rural population as well, and the total population on the watershed is about 450,000. The villages of Perrysburg and Maumee, with a population of 1,800 each, are situated only 5 miles above Toledo's waterworks intake.

Napoleon, with a population of 2,700, is situated 37 miles above. Much more important as a factor in waterborne disease is the sewage of Toledo itself, which is discharged into the Maumee at various points below the intake to the mouth of the river.

The Maumee River, from the foot of the rapids to its mouth, a distance of 16 miles, is an estuary whose current is dependent upon the lake level and the action of the wind.

The pronounced fluctuations in the level of the western end of Lake Erie due to winds produce very marked currents.

Observations of the United States Engineer Department show that in 1889 the water dropped to 11 feet below the normal stage. In 1893 it reached within 2 inches of this record. High water may reach 6 feet above normal, due to wind alone, and with the interference of ice has been as high as 14 feet above the normal stage. Such fluctuations of level explain the fact that the current in this portion of the Maumee may be either toward the lake or southwestward toward Perrysburg.

This is important, as Toledo's own sewage is thus carried back over the waterworks intake. Thus Toledo's waterworks intake is probably polluted at all times, regardless of the direction of wind and current. In spite of this well-known fact, filtration of the public water supply was not an accomplished fact until February 26, 1910.

In 1903 an engineering commission [1] composed of C. H. Benzenberg, Allen Hazen, and William G. Clark reported upon an improved water supply for Toledo. After reviewing the possible sources of supply the commission recommended as follows:

> In regard to their relative cost, taking into account both the expense of construction and operation, the advantage lies with the Maumee River scheme. The estimated cost of construction, to meet the requirements up to 1920, on the latter project is \$773,190, while that on the lake project along the southern route is \$2,173,754, and that along the northern route is \$2,483,923, of which latter amount, however, \$431,200

[1] Benzenberg, C. H., Hazen, Allen, Clark, William G., Report of the Engineering Commission, appointed by the Waterworks Trustees, Toledo, Ohio, 1903.

are not chargeable to the pure-water supply problem. Taking into consideration both the cost of operation and the interest and sinking fund charges on the cost of construction due to the introduction of pure-water supply, such cost of the Maumee supply proves to be very much lower than that of the lake supply during the entire period to 1940, notwithstanding the relatively low cost of operation in connection with the lake supply.

The Maumee River supply has the further great advantage of extreme low cost of installation, as compared with every other available scheme, which places its construction unquestionably within the reach of the city and of its water department.

Upon a careful consideration of all questions bearing upon the proposed improved water supply for this city, your commission recommend that the Maumee River be continued as the source of supply, that the water be taken from the main channel in the river nearly opposite the house of the country club, and that for that purpose and for the location of the necessary purification works an effort be made to secure the golf course of the country club. Should it not be possible to secure said property, then we recommend that so much of the low ground north of the golf course be secured as may be necessary for a low-lift pumping station and a roadway from there to Broadway, and about 25 acres of land located anywhere along the west side of Broadway, between a point west of the above proposed pumping station site and Delaware Creek.

We further recommend that upon these sites a low-lift pumping station and a suitable purification plant, with clear-water reservoir suitably equipped and in conformity with the requirements as set forth in the above report as necessary for the next 15 or 20 years, be erected and properly connected with each other and the main pumping station, as soon as possible. These works can thereafter be enlarged as the increased consumption may make it necessary, and the entire works should be designed in a comprehensive manner, so as to permit such extension without causing any derangement of any of its existing parts.

We further recommend that if at any time it should become possible for the city to secure the right to use water from the Miami and Erie Canal for a period of years in quantity sufficient to supply the consumption, a suitable connection should be made between the canal and the coagulation basins and that the supply be taken from the canal, and that the necessary betterments along the canal as indicated in our report be made. The reduction in cost of operation will amount to about $2 per million gallons drawn in this way.

We further recommend that such purification plant be thereupon placed in charge of a competent and experienced person to operate it, and we are satisfied that the purified Maumee River water will prove to be an ample supply of pure and wholesome water.

The plant was constructed along the general lines suggested. Besides being structurally admirable, the Toledo filter plant has the additional advantage of expert supervision.

The plant consists of 20 units, each having a capacity of 1,000,000 gallons daily. It is planned to add 16 new units and increase the storage of clear water, giving a proposed capacity of 36,000,000 gallons daily through the filters and a storage of filtered water of 16,000,000 gallons.

The percentage of persons using city water in Toledo is low compared with other cities. For years the Maumee water furnished was of such appearance that self-respecting persons would not drink it. For this reason the number of wells in Toledo has always been large. Since the installation of the filter plant considerable increase in the

number of house connections has followed. There are about 15,000 metered house connections, and probably one-half of the population still uses well water. The proportion using well water will steadily decrease as confidence in the city supply is established. Over 1,500 new house connections were made in 1910.

*Milk.*—The milk-inspection service of Toledo is under the board of health. The veterinarian in charge of milk inspection is hampered by lack of personnel. The farms inspected are rated on the score-card system. The city inspection of milk is carried out with the idea of securing cleanliness. Most of the action, including laboratory examination, is directed toward maintaining a high standard of cream, and no work is being done upon the bacterial contents of milk. Considerable milk comes into Toledo from sources beyond control of the city; some of it from Indiana and Michigan. Altogether the milk situation in Toledo leaves much to be desired.

*Garbage.*—The collection of garbage in Toledo is under the street department, and the city now has a contract with a private firm for its disposal by reduction.

### SEWER SYSTEM.

The entire sewer system of Toledo is of the combined type. Some of the very large sewers on the north side of the river, discharging near its mouth, carry very little sewage, but storm water and drainage from swampy districts.

The same is true of sewers emptying into Tenmile Creek. No sanitary sewers are being constructed, and the problem of disposal will be complicated by the combined system in vogue.

The entire sewage of Toledo goes into the Maumee River with the exception of sewage going into Tenmile Creek and Swan Creek. As Swan Creek discharges into the Maumee at the foot of Monroe Street it is scarcely an exception.

Tenmile Creek receives one 72-inch sewer, one 60-inch, two 54-inch, one 30-inch, and one 24-inch.

Draining the northern portion of the city, Tenmile Creek empties into Maumee Bay.

No change in the sewer system is contemplated. A trunk sewer to intercept sewer outlets entering the river above Toledo's water-works intake has been approved by the State board of health and now awaits the action of the county commissioners. This will cut off considerable pollution within a comparatively short distance of the intake, but Toledo's own sewage goes into the river below the intake and is readily carried back over the intake by the current, which is frequently reversed by wind action or a rising lake level.


94972°—Bull. 77—11. (To face page 160.)

MAP 16.—Toledo, Ohio, showing sewer outlets, waterworks intake, and filter plant.

### TYPHOID FEVER.

Typhoid fever has had a high rate of prevalence in Toledo for years. The lowest death rate per 100,000 for the past 10 years was 20.5 in 1903; the highest, 45.7 in 1905.

The death rate from typhoid fever has not only been high, but has been remarkably consistent. Since 1880 the number of typhoid deaths annually has increased proportionately with the increase of population plus a slight additional increase.

*Average number of deaths from typhoid fever per 100,000 population for three decades.*

| | |
|---|---|
| 1881–1890 | 30.6 |
| 1891–1900 | 34.8 |
| 1901–1910 | 36.8 |

In studying Toledo statistics one is struck by the regular prevalence of typhoid fever. This prevalence does not depend upon explosive outbreaks, but upon a steady continuous prevalence which varies little from year to year.

In the absence of marked epidemics of an explosive character to account for the persistently high rate, one is forced to conclude that conditions which favor a very high endemic rate exist in Toledo.

### SEASONAL PREVALENCE.

The seasonal prevalence is indicated by Chart LIII, based on total deaths from typhoid fever for 10 years by months.

The rise beginning in July and reaching its apex in September is characteristic of typhoid due to factors other than the public water supply. Not only is the total monthly prevalence for 10 years indicative of endemic typhoid, but the individual years furnish charts almost equally characteristic, with the exception of 1904 and 1909.

Morbidity statistics for typhoid fever in Toledo are available from 1903 to date. A glance at the table given below for 1903 will suffice to show the fallacy of attempting to draw conclusions from typhoid morbidity statistics.

| Months. | Cases reported. | Number of deaths. | Months. | Cases reported. | Number of deaths. |
|---|---|---|---|---|---|
| January | 2 | 1 | August | 11 | 5 |
| February | 3 | 2 | September | 10 | 8 |
| March | 3 | 1 | October | 18 | 6 |
| April | 2 | 2 | November | 7 | 6 |
| May | 1 | 2 | December | 1 | 5 |
| June | 0 | 1 | | | |
| July | 1 | 1 | Total | 59 | 40 |

The prevalence of typhoid can be estimated with fair accuracy by multiplying the deaths by 10. As the mortality statistics are more reliable than the morbidity statistics, charts made on this basis for each year indicate a seasonal prevalence corresponding in a general way with Chart LVI, based upon the total deaths by months for 10 years. 1904 and 1909 are exceptions. These years were atypical, and Charts LVII and LVIII indicate an outbreak in June, 1904, and January, 1909; or, making correction for time elapsed before death, in May, 1904, and December, 1908. These outbreaks may have been

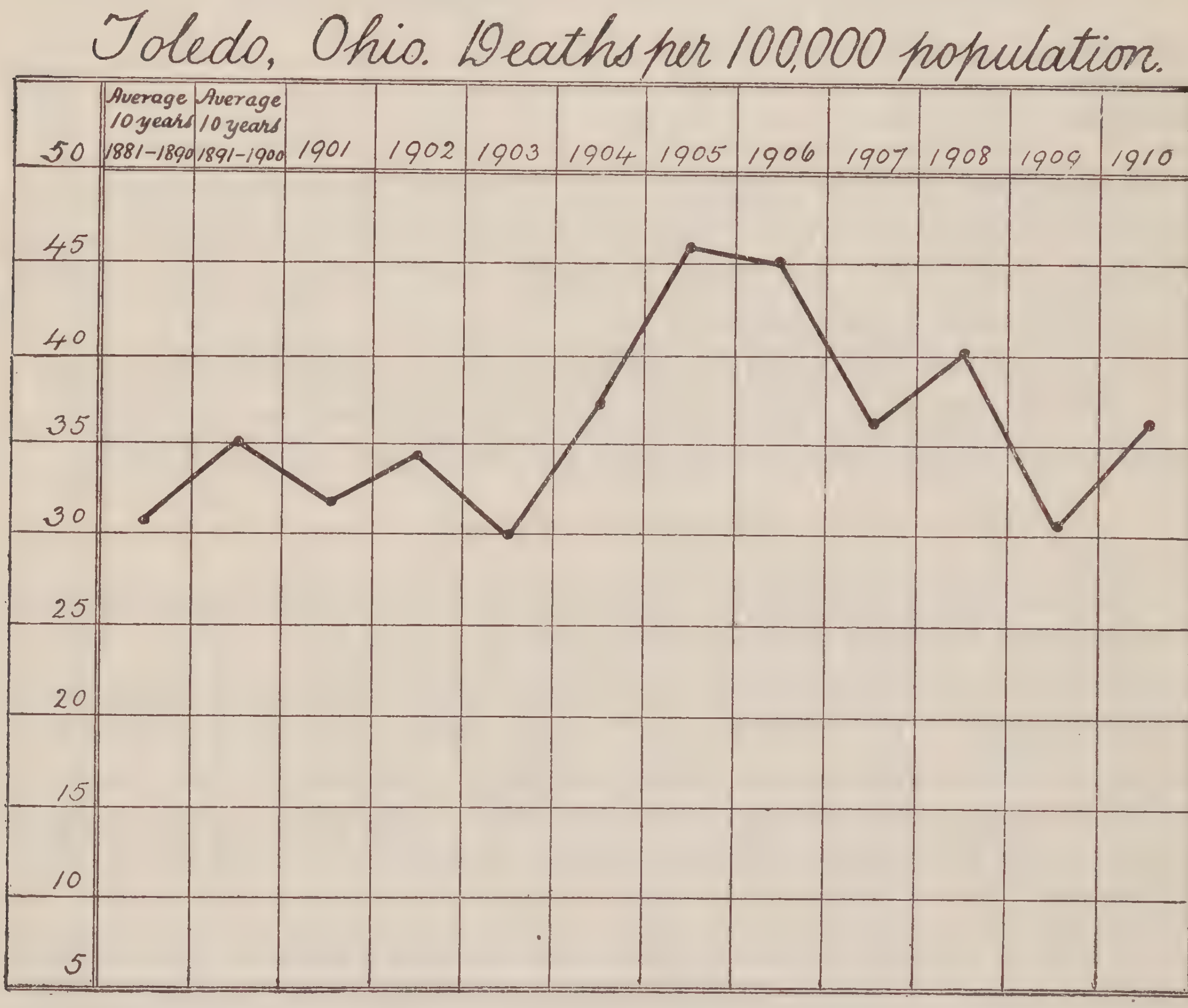


CHART LII.—Toledo, Ohio, typhoid fever: Deaths per 100,000, by years, 1881–1910. Note the slight variation from year to year. Filter plant was installed February 1910.

due to water, but in the rest of the 10-year period there is no suggestion of an explosive outbreak in the record.

It is known that the public water supply, taken from the Maumee River and delivered unfiltered until 1910, was grossly polluted with sewage and capable of causing a very high typhoid-fever rate. In spite of this known fact, upon examining the data and local conditions in Toledo, a question arises as to the part played by the public water supply in the continued prevalence of typhoid fever.

As to facts for and against the Toledo water supply as a factor in typhoid transmission the following may be cited, suggesting water as an agent: (1) Potentiality for disaster—a public water supply grossly

## ERRATA.

On page 162, line 5, Chart LVI should read Chart LII.
In line 7, same page, Charts LVII and LVIII should read Charts LIV and LV.

Toledo, Ohio. Deaths, Typhoid Fever.
total for 10 years, 1901-1910, by Months.

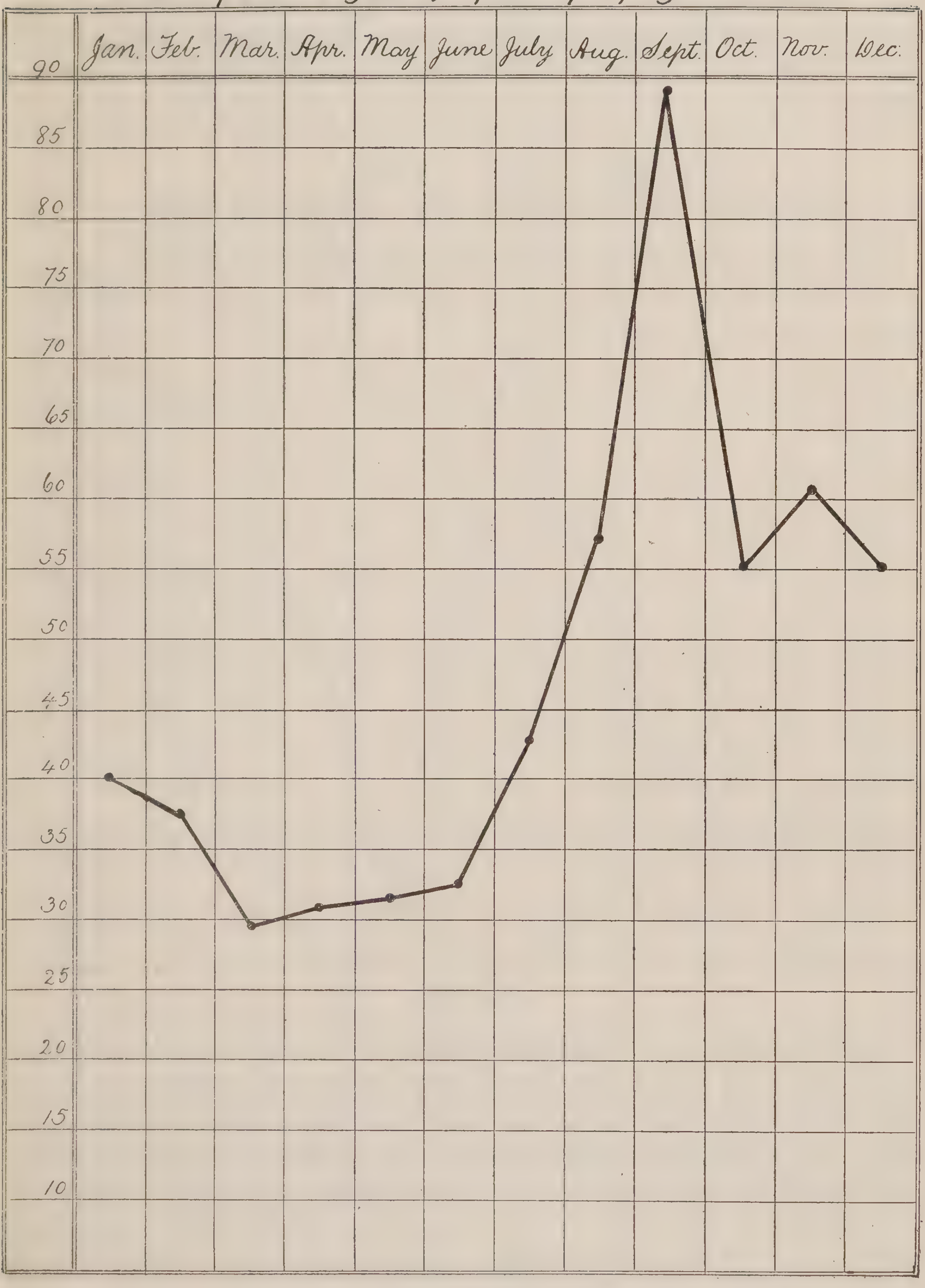


CHART LIII.

Note the predominance of cases in September and low rate in winter and spring.

polluted by sewage, delivered unfiltered and untreated to consumers; (2) outbreaks in May, 1904, and December, 1908, which may have been due to the water supply; (3) a small number of ignorant people who drank the city water without boiling; (4) laborers and others who used well water at home but drank city water while at work; (5) city water was probably used in washing receptacles for milk and in other ways was brought into relation to the purveying of food and drink.

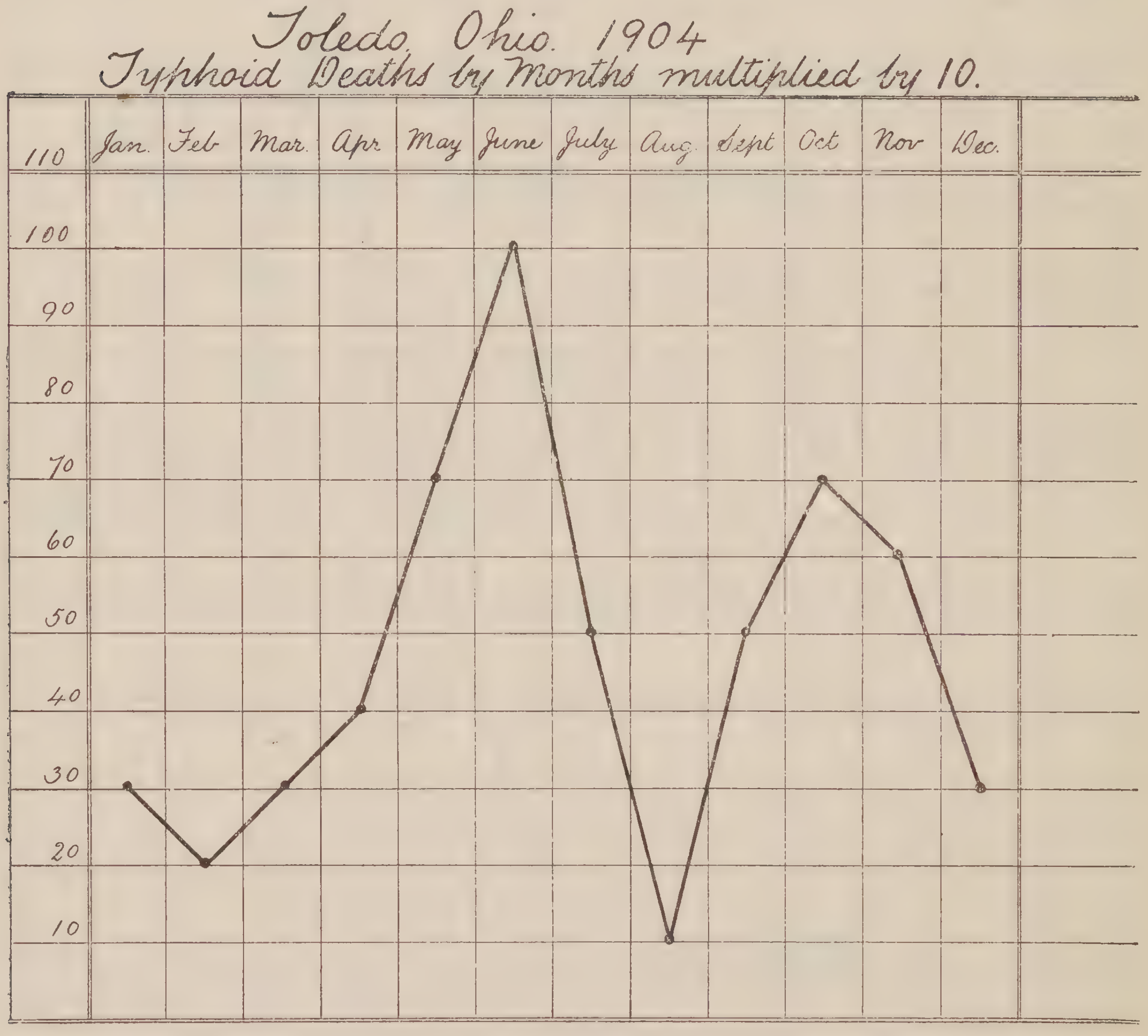


CHART LIV.

Those against water transmission are: (1) About one-half the population used only well water; (2) the great bulk of the remainder would not drink the repulsive looking raw water, but used boiled or bottled water; (3) the typhoid prevalence was in the typhoid season in every year for 20 years except an occasional outbreak, such as May, 1904, and December, 1908; (4) the furnishing of a safe filtered water for 10 months in 1910 did not lower the typhoid rate; on the contrary, the rate rose from 31.5 in 1909 to 36 in 1910.

It is clear that the public water supply of Toledo was not responsible for the continuously high typhoid-fever rate. It may have contributed a small number of cases to the total each year and in certain

years been responsible for certain outbreaks, but the steady prevalence of typhoid in Toledo for years is due to bad sanitary conditions independent of the public water supply.

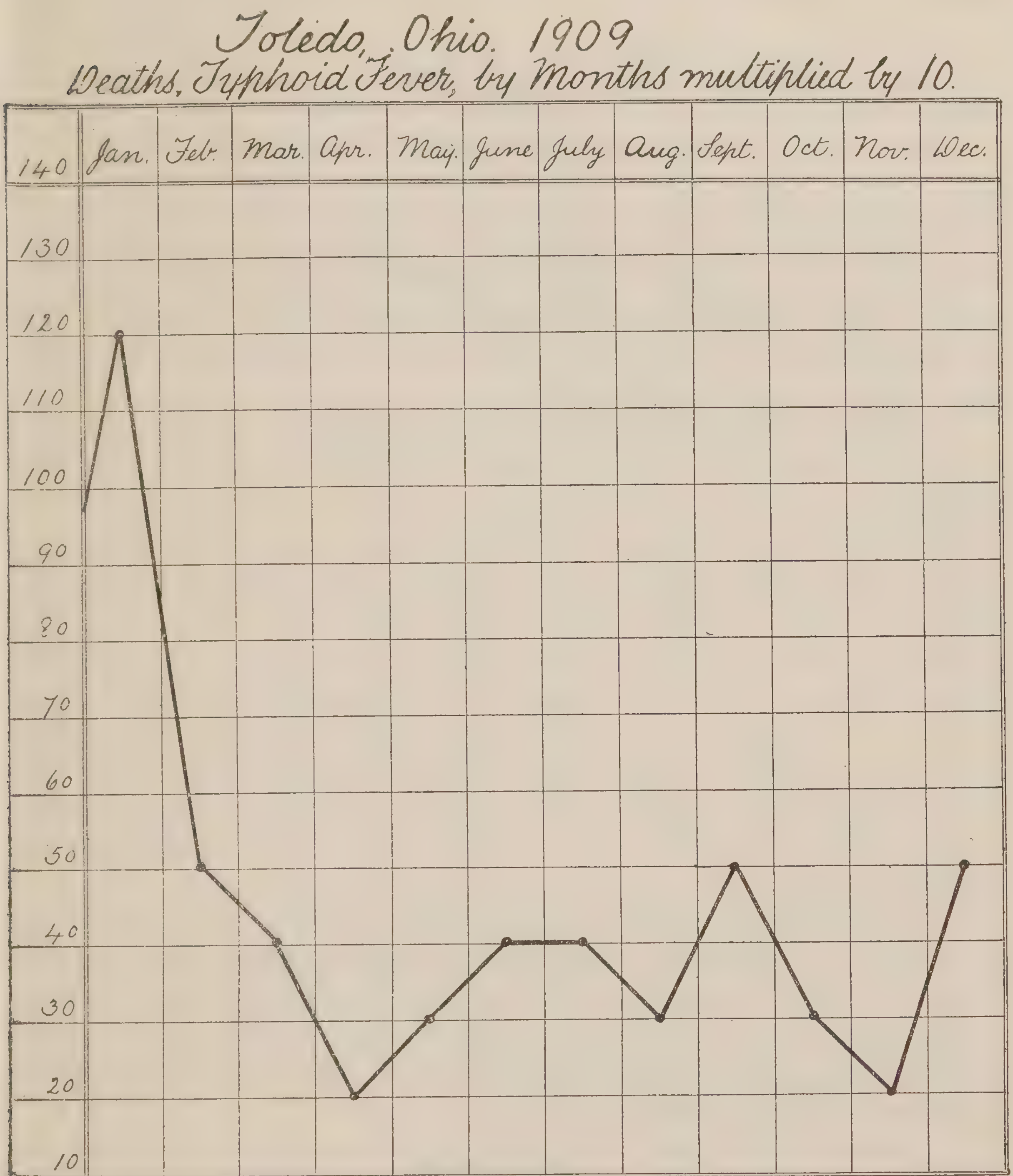


CHART LV.

An analysis of 59 cases of typhoid fever which were reported at the health office in Toledo from November, 1910, to March, 1911, showed the following facts concerning the class of water used and the closet facilities:

*Water supply.*

| | |
|---|---|
| Wells | 41 |
| City water | 17 |
| Bottled water | 1 |
| Total | 59 |

*Closet facilities.*

| Type. | Condition. | | Total. |
|---|---|---|---|
| | Good. | Bad. | |
| Out-door privy | 4 | 28 | 32 |
| Inside flush | 24 | 3 | 27 |
| Total | 28 | 31 | 59 |

Conclusions of a positive nature can not be based upon such a small series of cases. The board of health preserves no epidemiologic data, and the only record of typhoid is the cases and deaths reported. The 59 cases referred to indicate that a large percentage of the typhoid cases occurs in users of well water.

In regard to the closet facilities and conditions of the closets, 31 of the 59 had closets in bad condition, and 28 of the 31 were out-door privies.

These facts as to wells and closets do not prove that either closet or well was responsible for the infection, but indicate rather the insanitary surroundings accompanying typhoid fever in Toledo.

Probably one-half the citizens use well water for drinking purposes. Many of these wells are contaminated with fecal bacteria. From January to March, 1911, the city bacteriologist examined water from 309 wells and found 102 grossly polluted and unfit for drinking purposes. Thousands of insanitary privies still exist, although over 1,400 sewer connections were made, due to the work of the board of health in 1910.

Unfortunately the board of health lacks or does not exercise full authority over dangerous contaminated wells. After discovery of a dangerous contaminated well the board of health limits its activity to affixing a notice on the pump setting forth the dangerous character of the water. In many cases the householder and the neighbors continue to use the water.

## CONCLUSIONS.

1. Conneaut has no sewage-disposal plant and the sewers discharge into the harbor.

The waterworks intake is exposed to sewage pollution, and public safety demands filtration or treatment of the water. Filtration plant was installed in 1900.

Typhoid fever has been excessive in Conneaut in the past, due to faulty construction, careless operation, or overworking of the filter plant.

The structural defects have been overcome to some extent. Overworking the plant is still possible, as there is no rate controller.

Careless operation is still possible, but good filter efficiency can be secured if the filters are properly operated. Careless operation can be prevented by close supervision by the State authorities.

2. Ashtabula's sewers discharge into the harbor; there is no sewage-disposal plant.

The water supply is taken from an intake exposed to sewage pollution, and Ashtabula has suffered severely from typhoid fever, undoubtedly due to polluted water taken from the lake.

A filtration plant was installed in March, 1909. The plant is capable of good filter efficiency, depending upon intelligent operation. The necessity of close supervision and frequent inspection is obvious and more imperative because of the gross pollution of the lake in the vicinity of the Ashtabula River. If proper sewage disposal were effected, the work of the filter plant would be simplified and accidents to the mechanism would not be likely to produce the tragic consequences which have followed such accidents in other places.

3. The lake in the vicinity of Fairport is polluted with the sewage of Fairport, Richmond, and Painesville. Some change is necessary in the water-supply system of these three towns. The present natural-sand filtration system is inadequate, and at times an emergency intake is used. Through the emergency intake untreated polluted lake water is delivered to the consumers. The raw sewage from these towns should not be discharged into river or lake, and an adequate supply of safe water should be furnished.

4. Gross pollution of the Black River and Lake near its mouth by the sewage of Lorain makes purification of the water supply imperatively necessary.

A filter plant was installed in 1896. Its history shows the effect of a filter plant properly operated in reducing typhoid fever rates. It also shows, unfortunately, the effect of careless operation and overworking of a filter plant beyond its capacity.

The sewage of Lorain still goes untreated into harbor and lake.

The filter plant has been enlarged and is now capable of good filter efficiency. First-class filter efficiency is vital and an absolute necessity so long as the raw sewage of Lorain is poured into the Black River. Proper sewage disposal would relieve the strain on the filter plant and make the seemingly inevitable accidents to filter plants less serious in their consequences under existing conditions. Very close supervision of the plant by the State authorities is necessary.

5. The entire sewage of Sandusky is discharged untreated into Sandusky Bay. Taking the water supply from such a source and delivering it unfiltered to the consumers had the usual result—serious waterborne typhoid epidemics. So long as Sandusky discharges raw sewage into Sandusky Bay water-borne typhoid can be prevented only by a very high filter efficiency.

A filter plant was installed in February, 1909. It has serious structural defects, and one unit can not be thrown out of service without shutting down the entire filter plant. The result of this was shown above in December, 1910, and January, 1911. The capacity of the plant is too small, and in addition to increasing its capacity the other serious defect should be remedied.

6. The entire sewage of the city of Cleveland is discharged into Lake Erie either direct or by means of the Cuyahoga River, without treatment. The present Cleveland intake is polluted at times by material carried out by the Cuyahoga River. This is especially likely to occur in high stages of the river coupled with a falling lake level. Other factors aiding the process are the presence of ice covering the surface and strong south or southeast winds.

With the amount of dilution, great explosive epidemics are unlikely to occur. However, from a close study of the data it seems certain that the epidemic of March and April, 1910, was due to a polluted water supply, and it is probable that less pronounced outbreaks and numerous cases of typhoid fever are also due to the same source.

In view of these facts it is evident that a water supply for Cleveland which would be safe every day in the year can not be secured from the present intake without filtration or treatment.

The intercepting sewer system is nearing completion and the sewage flow of the entire city will be removed from the lake and harbor, to be discharged at a point in the lake 8.2 miles east of the intake.

Pollution of the intake is also possible under certain weather conditions from Cleveland's sewage, discharged 8.2 miles east of the intake. Weather conditions referred to which are most probable for pollution of the intake are those which produce a strong current from northeast to southwest. This current is produced, as previously described, during the return of the lake to stable equilibrium following disturbance by strong southwest winds or gales. It can be produced also by strong winds or gales blowing from the northeast or east.

The northeast winds or gales produce a surface current. The current from northeast to southwest following southwest winds or gales without change of wind is an undercurrent. The amount of water available for dilution is so great that infection would be dilute even under storm conditions with a current of considerable velocity.

7. All the sewage of Toledo is discharged into the Maumee River, with the exception of a small amount carried to Maumee Bay by Ten Mile Creek. Direction of the current in the Maumee depends upon the direction and velocity of the wind and the level of the lake. The Maumee River's fluctuations resemble those of a tidal estuary, and the waterworks intake placed above the outfalls of the city sewers is still exposed to pollution from them.

The water entering Toledo's intake is grossly polluted, and only high filter efficiency renders it safe for drinking purposes.

The filter plant is modern and under expert superintendence. On account of the high bacterial count in the raw water it is necessary to supplement the filtration process by the addition of hypochlorite of lime at times.

The installation of a safe water supply in Toledo did not effect a reduction in the typhoid fever deaths per 100,000 population. For years the bulk of the cases occurred in the autumn months and comparatively few in winter and spring. A very large part of the population did not use the city water for drinking. The city water may have had some influence on typhoid fever rates in the past, but probably played a minor role at any time. At present Toledo's high typhoid fever rate must be charged to other causes.

There are too many contaminated and dangerous wells in use in Toledo. There remains much to be done in the elimination of insanitary privies and control of milk. Only about 50 per cent of typhoid fever cases are reported and there is no system of adequate control over these.

## LIST OF HYGIENIC LABORATORY BULLETINS OF THE PUBLIC HEALTH AND MARINE-HOSPITAL SERVICE.

The Hygienic Laboratory was established in New York, at the Marine Hospital on Staten Island, August 1887. It was transferred to Washington, with quarters in the Butler Building, June 11, 1891, and a new laboratory building, located in Washington, was authorized by act of Congress, March 3, 1901.

The following *bulletins* [Bulls. Nos. 1–7, 1900 to 1902, Hyg. Lab., U. S Mar.-Hosp. Serv., Wash.] have been issued:

*No. 1.—Preliminary note on the viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 2.—Formalin disinfection of baggage without apparatus. By M. J. Rosenau.

*No. 3.—Sulphur dioxid as a germicidal agent. By H. D. Geddings.

*No. 4.—Viability of the *Bacillus pestis*. By M. J. Rosenau.

No. 5.—An investigation of a pathogenic microbe (*B. typhi murium* Danyz) applied to the destruction of rats. By M. J. Rosenau.

*No. 6.—Disinfection against mosquitoes with formaldehyde and sulphur dioxid. By M. J. Rosenau.

No. 7.—Laboratory technique: Ring test for indol, by S. B. Grubbs and Edward Francis; Collodium sacs, by S. B. Grubbs and Edward Francis; Microphotography with simple apparatus, by H. B. Parker.

By act of Congress approved July 1, 1902, the name of the "United States Marine-Hospital Service" was changed to the "Public Health and Marine-Hospital Service of the United States," and three new divisions were added to the Hygienic Laboratory.

Since the change of name of the service the bulletins of the Hygienic Laboratory have been continued in the same numerical order, as follows:

*No. 8.—Laboratory course in pathology and bacteriology. By M. J. Rosenau. (Revised edition, March, 1904.)

*No. 9.—Presence of tetanus in commercial gelatin. By John F. Anderson.

*No. 10.—Report upon the prevalence and geographic distribution of hookworm disease (uncinariasis or anchylostomiasis) in the United States. By Ch. Wardell Stiles.

*No. 11.—An experimental investigation of *Trypanosoma lewisi*. By Edward Francis.

*No. 12.—The bacteriological impurities of vaccine virus; an experimental study. By M. J. Rosenau.

*No. 13.—A statistical study of the intestinal parasites of 500 white male patients at the United States Government Hospital for the Insane; by Philip E. Garrison, Brayton H. Ransom, and Earle C. Stevenson. A parasitic roundworm (*Agamomermis culicis* n. g., n. sp.) in American mosquitoes (*Culex sollicitans*); by Ch. Wardell Stiles. The type species of the cestode genus *Hymenolepis*; by Ch. Wardell Stiles.

*No. 14.—Spotted fever (tick fever) of the Rocky Mountains; a new disease. By John F. Anderson.

*No. 15.—Inefficiency of ferrous sulphate as an antiseptic and germicide. By Allan J. McLaughlin.

*No. 16.—The antiseptic and germicidal properties of glycerin. By M. J. Rosenau.

*No. 17.—Illustrated key to the trematode parasites of man. By Ch. Wardell Stiles.

*No. 18.—An account of the tapeworms of the genus *Hymenolepis* parasitic in man, including reports of several new cases of the dwarf tapeworm (*H. nana*) in the United States. By Brayton H. Ransom.

*No. 19.—A method for inoculating animals with precise amounts. By M. J. Rosenau.

*No. 20.—A zoological investigation into the cause, transmission, and source of Rocky Mountain "spotted fever." By Ch. Wardell Stiles.

*No. 21.—The immunity unit for standardizing diphtheria antitoxin (based on Ehrlich's normal serum). Official standard prepared under the act approved July 1, 1902. By M. J. Rosenau.

*No. 22.—Chloride of zinc as a deodorant, antiseptic, and germicide. By T. B. McClintic.

*No. 23.—Changes in the Pharmacopœia of the United States of America. Eighth Decennial Revision. By Reid Hunt and Murray Galt Motter.

No. 24.—The International Code of Zoological Nomenclature as applied to medicine. By Ch. Wardell Stiles.

*No. 25.—Illustrated key to the cestode parasites of man. By Ch. Wardell Stiles.

*No. 26.—On the stability of the oxidases and their conduct toward various reagents. The conduct of phenolphthalein in the animal organism. A test for saccharin, and a simple method of distinguishing between cumarin and vanillin. The toxicity of ozone and other oxidizing agents to lipase. The influence of chemical constitution on the lipolytic hydrolysis of ethereal salts. By J. H. Kastle.

*No. 27.—The limitations of formaldehyde gas as a disinfectant, with special reference to car sanitation. By Thomas B. McClintic.

*No. 28.—A statistical study of the prevalence of intestinal worms in man. By Ch. Wardell Stiles and Philip E. Garrison.

*No. 29.—A study of the cause of sudden death following the injection of horse serum. By M. J. Rosenau and John F. Anderson.

*No. 30.—I. Maternal transmission of immunity to diphtheria toxin. II. Maternal transmission of immunity to diphtheria toxin and hypersusceptibility to horse serum in the same animal. By John F. Anderson.

*No. 31.—Variations in the peroxidase activity of the blood in health and disease. By Joseph H. Kastle and Harold L. Amoss.

*No. 32.—A stomach lesion in guinea pigs caused by diphtheria toxin, and its bearing upon experimental gastric ulcer. By M. J. Rosenau and John F. Anderson.

*No. 33.—Studies in experimental alcoholism. By Reid Hunt.

*No. 34.—I. *Agamofilaria georgiana* n. sp., an apparently new roundworm parasite from the ankle of a negress. II. The zoological characters of the roundworm genus *Filaria* Mueller, 1787. III. Three new American cases of infection of man with horsehair worms (species *Paragordius varius*), with summary of all cases reported to date. By Ch. Wardell Stiles.

*No. 35.—Report on the origin and prevalence of typhoid fever in the District of Columbia. By M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle. (Including articles contributed by Ch. Wardell Stiles, Joseph Goldberger, and A. M. Stimson.)

*No. 36.—Further studies upon hypersusceptibility and immunity. By M. J. Rosenau and John F. Anderson.

*No. 37.—Index-catalogue of medical and veterinary zoology. Subjects: Trematoda and trematode diseases. By Ch. Wardell Stiles and Albert Hassall.

No. 38. The influence of antitoxin upon postdiphtheritic paralysis. By M. J. Rosenau and John F. Anderson.

*No. 39.—The antiseptic and germicidal properties of solutions of formaldehyde, and their action upon toxins. By John F. Anderson.

*No. 40.—1. The occurrence of a proliferating cestode larva (*Sparganum proliferum*) in man in Florida, by Ch. Wardell Stiles. 2. A reexamination of the type specimen of *Filaria restiformis* Leidy, 1880=*Agamomermis restiformis*, by Ch. Wardell Stiles. 3. Observations on two new parasitic trematode worms: *Homalogaster philippinensis* n. sp., *Agamodistomum nanus* n. sp., by Ch. Wardell Stiles and Joseph Goldberger.

4. A reexamination of the original specimen of *Tænia saginata abietina* (Weinland, 1858), by Ch. Wardell Stiles and Joseph Goldberger.

*No. 41.—Milk and its relation to the public health. By various authors.

*No. 42.—The thermal death points of pathogenic micro-organisms in milk. By M. J. Rosenau.

*No. 43.—The standardization of tetanus antitoxin (an American unit established under authority of the act of July 1, 1902). By M. J. Rosenau and John F. Anderson.

No. 44.—Report No. 2 on the origin and prevalence of typhoid fever in the District of Columbia, 1907. By M. J. Rosenau, L. L. Lumsden, and Joseph H. Kastle.

No. 45.—Further studies upon anaphylaxis. By M. J. Rosenau and John F. Anderson.

No. 46.—*Hepatozoon perniciosum* (n. g., n. sp.); a hæmogregarine pathogenic for white rats; with a description of the sexual cycle in the intermediate host, a mite (*Lelaps echidninus*). By W. W. Miller.

No. 47.—Studies on thyroid: I. The relation of iodine to the physiological activity of thyroid preparations. By Reid Hunt and Atherton Seidell.

No. 48.—The physiological standardization of digitalis. By Charles Wallis Edmunds and Worth Hale.

No. 49.—Digest of comments on the United States Pharmacopœia. Eighth decennial revision for the period ending December 31, 1905. By Murray Galt Motter and Martin I. Wilbert.

No. 50.—Further studies upon the phenomenon of anaphylaxis. By M. J. Rosenau and John F. Anderson.

No. 51.—Chemical tests for blood. By Joseph H. Kastle.

No. 52.—Report No. 3 on the origin and prevalence of typhoid fever in the District of Columbia (1908). By M. J. Rosenau, Leslie L. Lumsden, and Joseph H. Kastle.

No. 53.—The influence of certain drugs upon the toxicity of acetanilide and antipyrine. By Worth Hale.

No. 54.—The fixing power of alkaloids on volatile acids and its application to the estimation of alkaloids with the aid of phenolphthalein or by the Volhard method. By Elias Elvove.

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No. 65.—Facts and problems of rabies. By A. M. Stimson.

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